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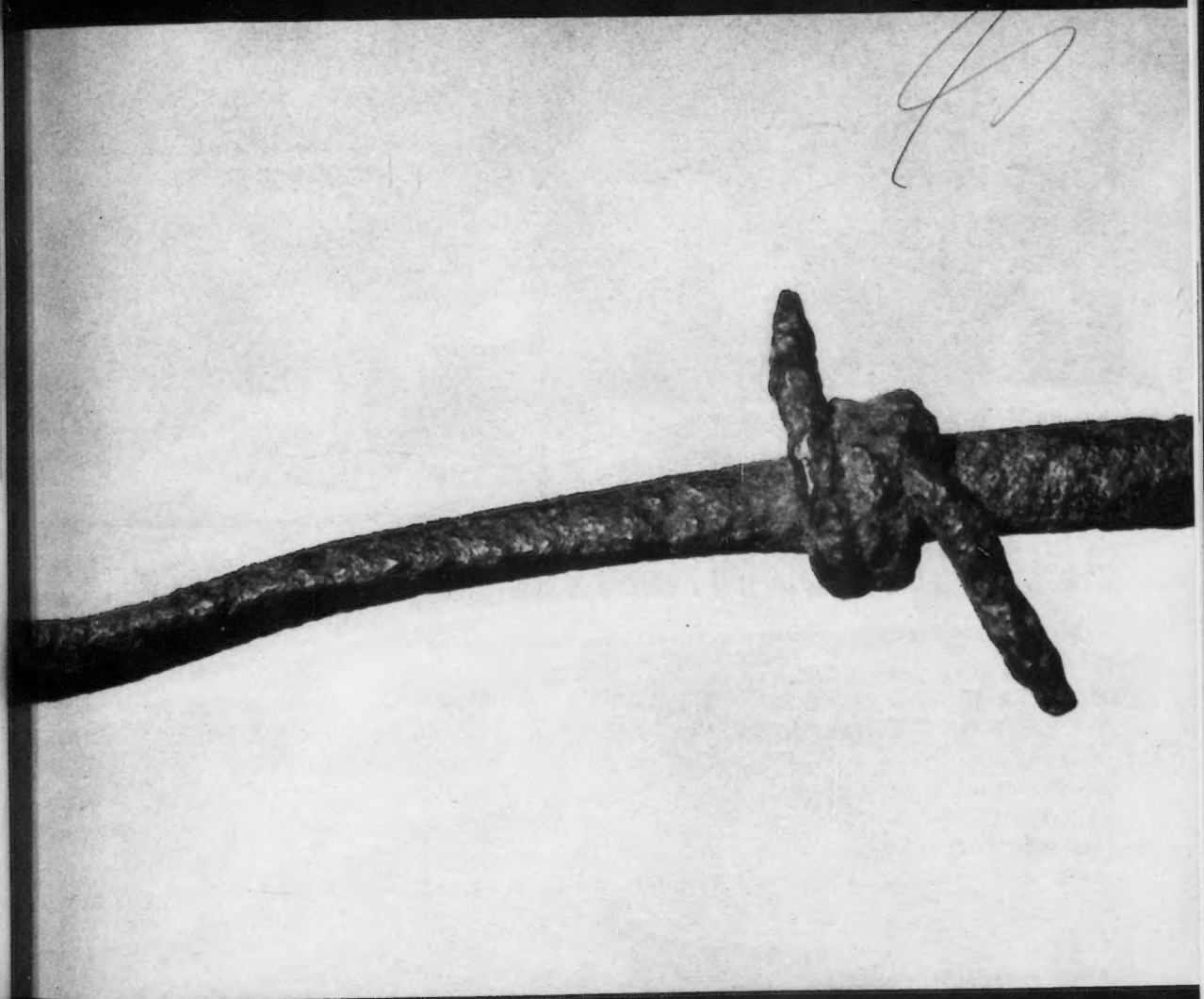

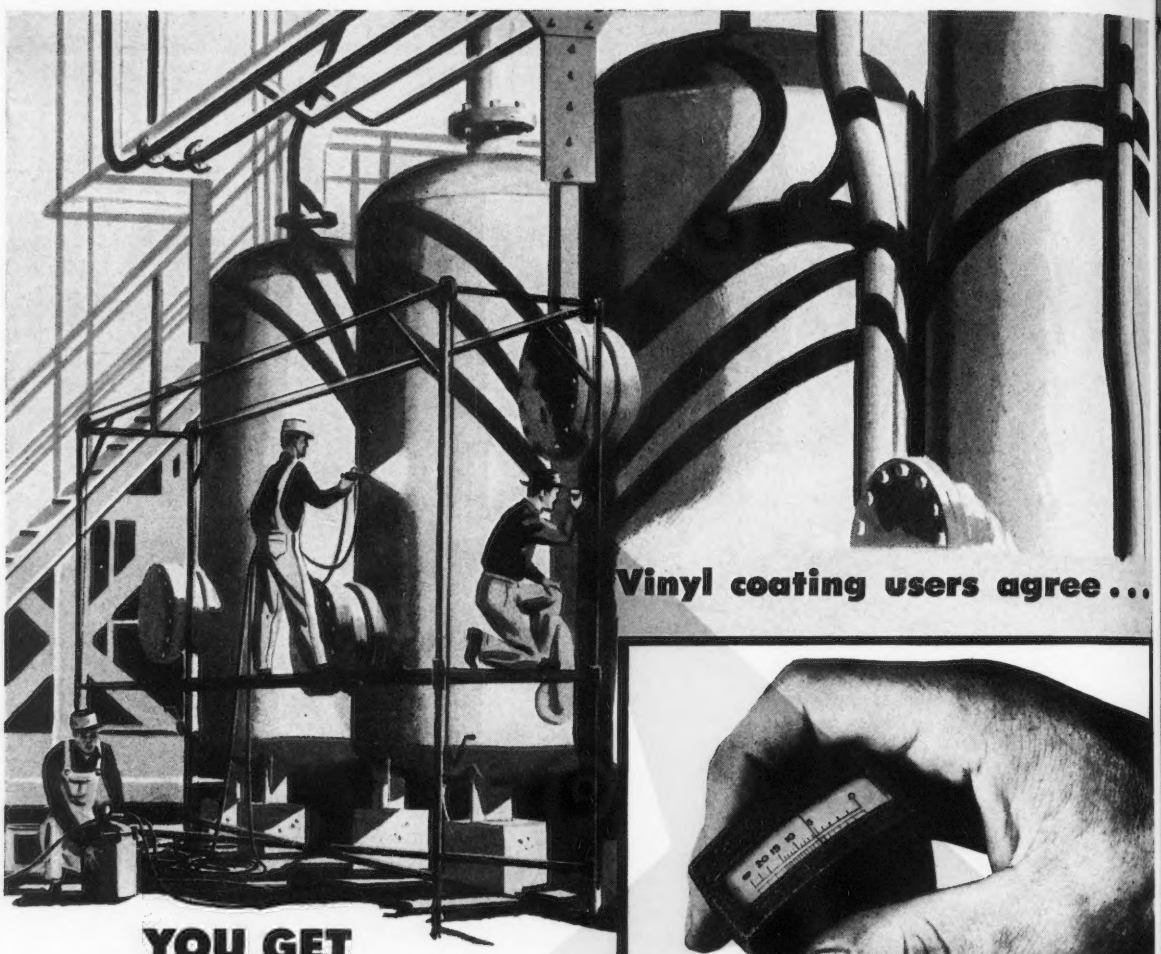

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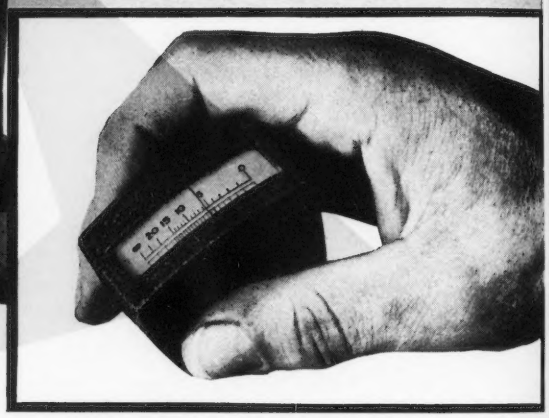

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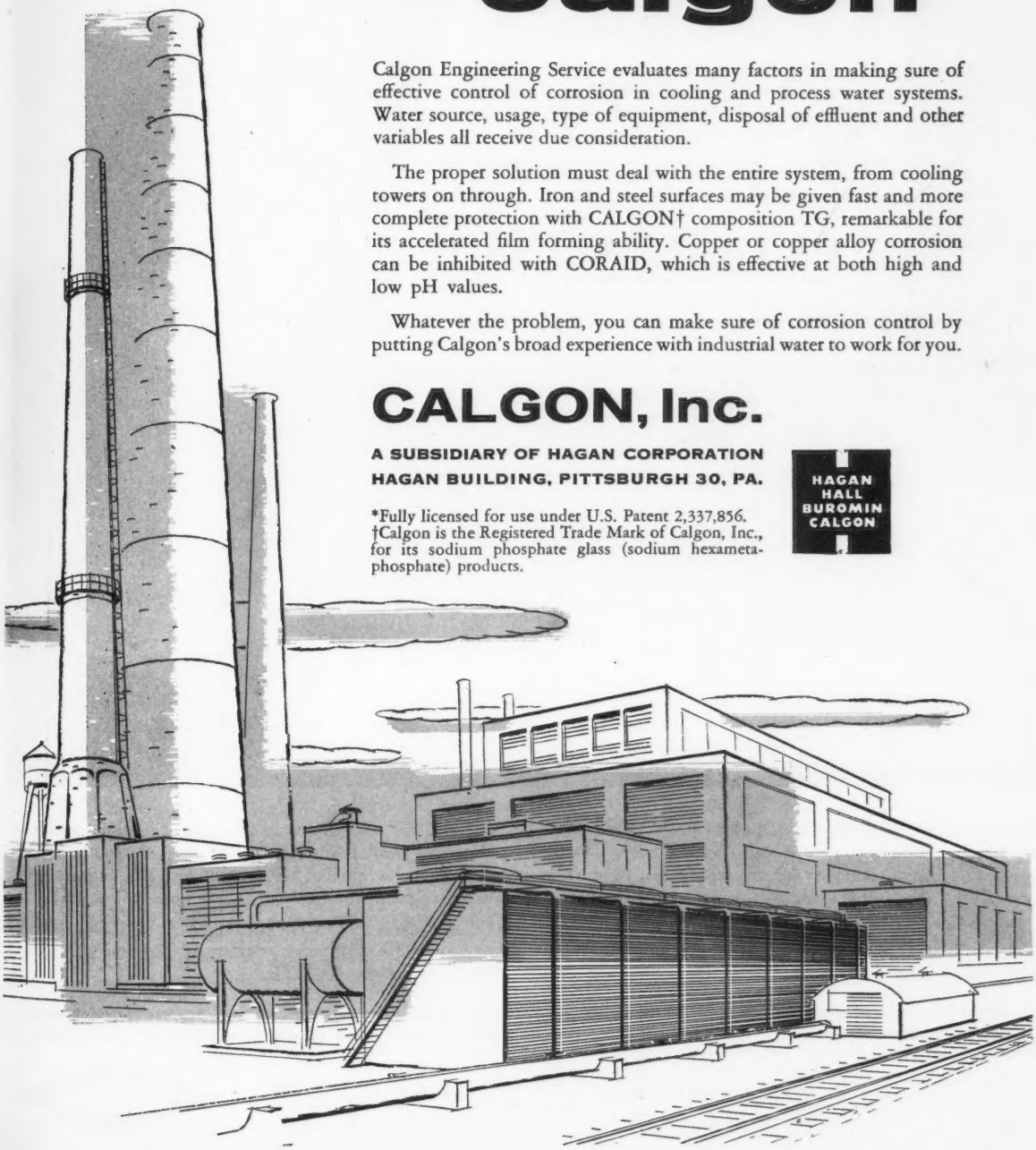

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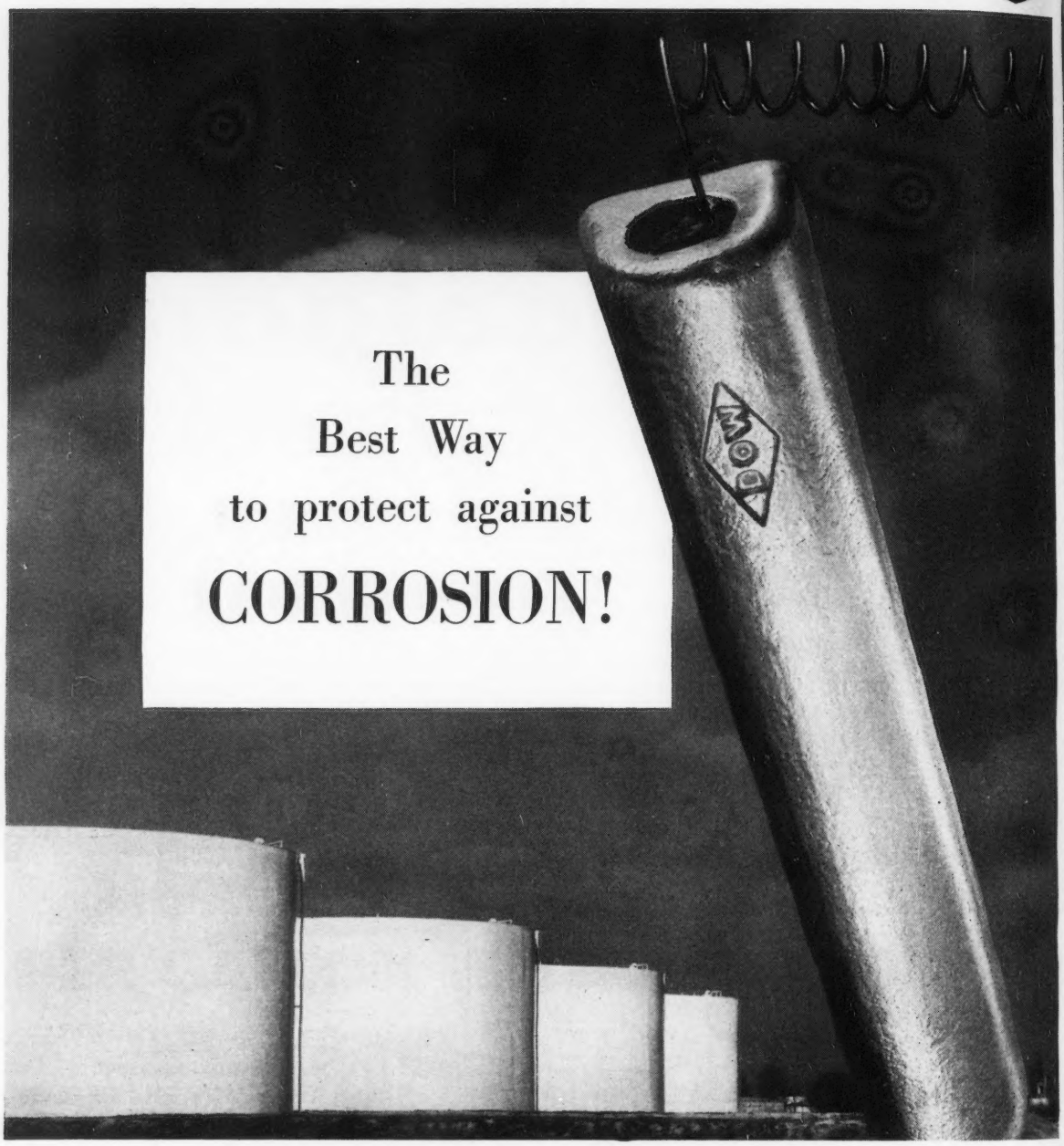

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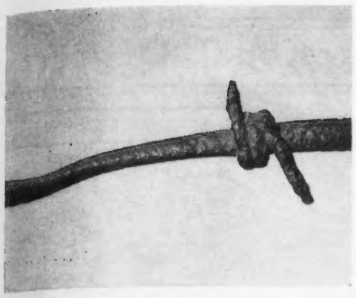

THIS MONTH'S COVER — This specimen of barbed wire was exposed 75 years on an Iowa farm. Two-pointed barbs probably were hand applied to the oval or possibly rectangular wire made under patents issued in 1875. Analysis showed steel to be copper-bearing, probably unintentionally. The steel probably was made by the basic open-hearth process. Further details are published in General News, Page 103.

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Gus Vogler, Trustee; Pipe Line Coating & Eng. Co., Box 264, Lafayette, La.

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Samuel E. Bosley, Secretary; 2947 E. 22nd St., Tulsa, Okla.

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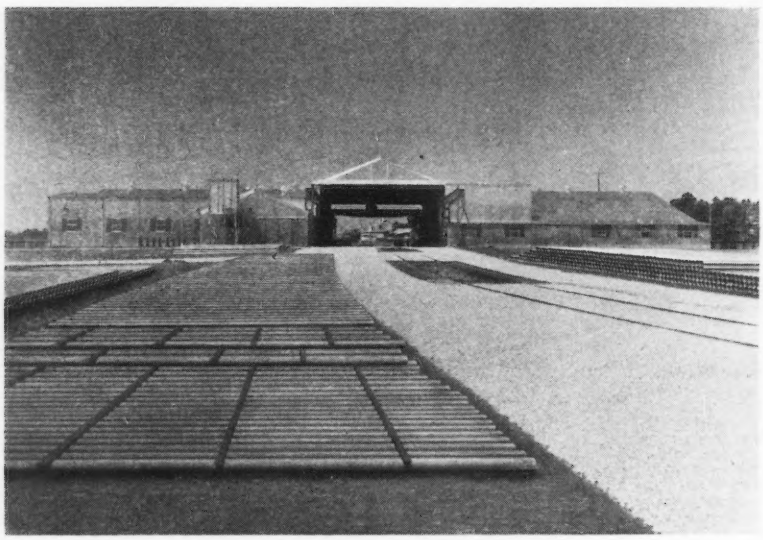
(Continued on Page 6)

EXPANDING
with East Texas!

NEW, LARGER PLS PLANT AT LONGVIEW

Provides the Most Modern Facilities for Coating and Wrapping



Keeping pace with the needs of pipe users in the East Texas area, Pipe Line Service has built this new, larger plant on the Texas & Pacific Railroad at Longview. Here you will find the most advanced type equipment for cleaning, priming, coating and wrapping steel pipe. With 22 acres, storage space is unexcelled, and transit privileges are available on shipments from pipe mills to destinations in surrounding states. It all adds up to better service than ever—more for your money in every foot of protection you buy.

DEPENDABLE SERVICE SINCE 1931

PLS Pipe Line Service Corporation

Pioneers in Steel Pipe Protection

General Offices and Plant: Franklin Park, Illinois

Plants at Glenwillard, Penna.; Longview, Texas; Corpus Christi, Texas; Harvey, La.; Sparrows Point, Md.; and Monmouth Junction, N.J.

Officers' Directory

(Continued From Page 5)

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E. F. Hensley, Secretary-Treasurer, The Dow Chemical Co., P. O. Box 351, Pittsburg, California.

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Carl T. Eyring, Secretary-Treasurer Salt River Project, Agricultural Improvement & Power District, 313 N. 3rd Ave., Phoenix, Arizona.

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Otto L. Hepner, Secretary-Treasurer; San Diego Water Dept., Alvarado Filtration Plant, La Mesa, California.

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John R. Culver, Sec.-Treas.; California Steel Products Co., 25 California St., San Francisco 11, Calif.

The Directory of NACE Technical Committees was published last in the January, 1955 issue of Corrosion beginning on Page 4.

CORROSION'S NO PROBLEM

...doing it the Dresser way!

Gas men find Dresser "Super-Service" Insulating Fittings and modern Dressertape* the fastest, easiest, most effective way to protect service lines against corrosion.

The rugged, flexible fittings are ready to use and simple to install. Time-proved Dresser insulating gaskets make joints 100% gastight, *effectively and permanently* block current flow, check corrosion.

Quick, easy and clean to apply, modern Dressertape readily conforms to irregular contours, bonds securely to pipe and fittings. Dressertape has exceptional chemical, physical and electrical properties that assure *positive and lasting corrosion protection!*

Ask your Dresser Sales Engineer about these and the many other Dresser products designed to help the gas industry solve any and all piping problems.

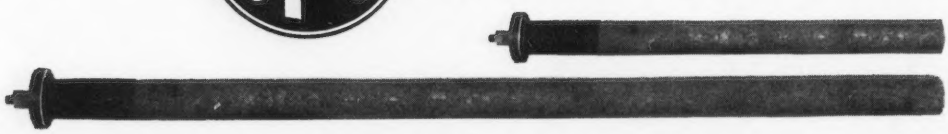
*Trademark of Dresser Mfg. Div.

DRESSER®

FITTING PARTNER FOR THE GAS INDUSTRY

Dresser Manufacturing Division, 59 Fisher Ave., Bradford, Pa. (One of the Dresser Industries). Warehouses: 1121 Rothwell St., Houston; 101 S. Airport Blvd., S. San Francisco. Sales Offices also in: New York, Philadelphia, Chicago, Toronto.

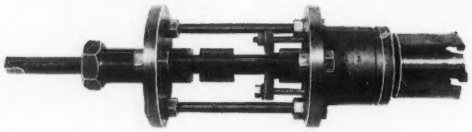
Now... CPS HTMA*



...IS STANDARD ACCESSORY EQUIPMENT WITH MOST MAJOR WATER VESSEL MANUFACTURERS!

This high purity solid thru-cored cast magnesium anode takes its place alongside our H T G A Anode for use in areas beyond the power line. The H T M A 30" or 60" offer these advantages:

1. **High full life efficiency provided by casting on a solid core, assuring perfect bonding.**
2. **Horizontal mounting is simple, sure and inexpensively installed in Victaulic nipples. Order all your new vessels equipped with Victaulic nipples for cathodic protection. Major manufacturers can furnish drawings of our recommended cathodic protection installation.**
3. **Grounding connection made external to tank allowing current control if desired.**
4. **Present equipment can be protected without the necessity of gas freeing by use of the below illustrated C P S Tapping Tool.**



5. **Standard interchangeable anodes assure a continued cathodic protection program.**
6. ***Low per pound Cost.***
7. **Full anode life . . . cast full anode length core eliminates sloughing off of any magnesium.**
8. **Field tested and proven by major oil companies.**

**C.P.S. Heater-treater magnesium anodes 30" & 60" assembled anodes ready for shipment illustrated.*

C P S - Progress thru Engineering

CPS

FIRST LINE MATERIALS INCLUDE:

Dow Magnesium Anodes
American Zinc Anodes
CPS Graphite Anodes
Good-All Rectifiers
Scotchrap Tape Coatings
Betzel Tapesters
Maloney Insulating Materials
Erico Cadweld Welding Materials
Fisher M-Scope Pipe and Cable Locators
Detectron Pipe Locators
Wahlquist Pipe Locators
CPS Graphite Anode Backfills
Homco and Barada and Page Backfills
Agra and CPS Meters
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Rubicon Potentiometers
Pearson Holiday Detectors
Holloway Shunts
Rome Direct-Burial Cable
Ditch-Witch Trenchers

cathodic protection service

Everything in the cathodic protection field . . . from an insulating washer to a turnkey contract installation.

OFFICES LOCATED IN HOUSTON
P. O. Box 6387
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Houston 6, Texas
Phone JA-5171

TULSA
314 Thompson Building
Tulsa, Okla.
Phone 2-9857

NEW ORLEANS
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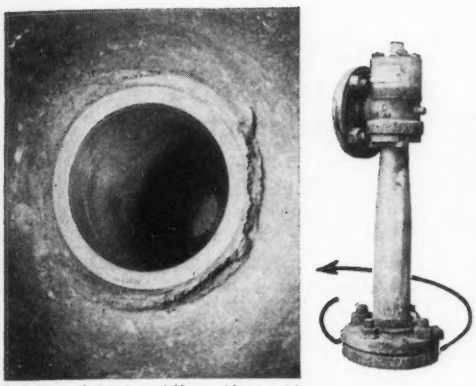
CORPUS CHRISTI
1522 So. Staples
Phone 3-7264

The best answer to many corrosion problems . . .

TITANIUM



End view of titanium diffuser. Note acid attack on cast iron flange.

Titanium steam jet diffuser easily passes 2 year acid test

Here's an instance of titanium's excellent performance under severe corrosive conditions. At a Du Pont Pigments plant a combination of chemical vapors and high-velocity steam proved too much for ordinary steam jet diffusers in service. Biting hydrochloric acid formed in the line and cut the service of cast iron diffusers to less than 3 months. Other diffusers of bronze and corrosion-resistant alloys were tried without improvement.

Finally, a diffuser of titanium was fabricated and installed. It's still on the job after a period of over 2 years of uninterrupted service—more than *ten times the average life of other diffusers!* And today, there's not a sign of wear or corrosion on the diffuser.

Resists chlorides and other corrosive chemicals as no other structural metal can!

Here are just a few of the corrosive environments where titanium offers corrosion resistance unmatched by common structural metals.

INORGANIC CHEMICALS	CONDITIONS	POSSIBLE APPLICATIONS
Ferric Chloride	0-30% at 100°C.	Process Piping,
Cupric Chloride	0-20% at 100°C.	Pumps, Valves,
Mercuric Chloride	All Conc. at 100°C.	Evaporators,
Aluminum Chloride	0-25% at 60°C.	Crystallizers,
Sodium Chloride	All Conc. at 100°C.	Kettles, Heat Exchangers
Sodium Hypochlorite	6% at 100°C.	Equipment for making bleaches
Chlorine Saturated Water	Room Temperature	Proportioning equipment
Wet Chlorine Gas	75°C.	Recovery equipment; electrolytic cells
Chromic Acid	10% and boiling	Plating equipment
Nitric Acid	0-70% at 100°C	Acid Heaters,
	60% at 195°C.	Nitrators
Sulphuric-Nitric Acid Mixture	40% sulphuric, 60% nitric at 35°C.	and Auxiliaries
Nitric-Adipic Mixtures	38% nitric—17% adipic at 90-95°C.	
ORGANIC CHEMICALS		
Chloroacetic Acid	100% at 100°C.	Chemical synthesis; equipment in manufacture of pharmaceuticals
Dichloroacetic Acid	100% at 100°C.	Chemical synthesis; equipment in manufacture of dyes

You can start your own evaluation tests now

As a pioneer *supplier* of titanium sponge, Du Pont can offer you expert technical help or put you in touch with manufacturers best equipped to work along with you. Considerable fabricating know-how and a wide variety of mill shapes are *now* available to help solve your corrosion problems. For more detailed information on titanium, just check the coupon below.

TITANIUM SPONGE

PIONEERED COMMERCIALLY BY DU PONT

DU PONT
REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

E. I. du Pont de Nemours & Co. (Inc.)
Pigments Department C-2
Wilmington 98, Delaware

☐ Please send me your new technical bulletin on the corrosion-resistant properties of titanium.

☐ Please send me your general booklet on titanium.

I am interested in using titanium for:_____

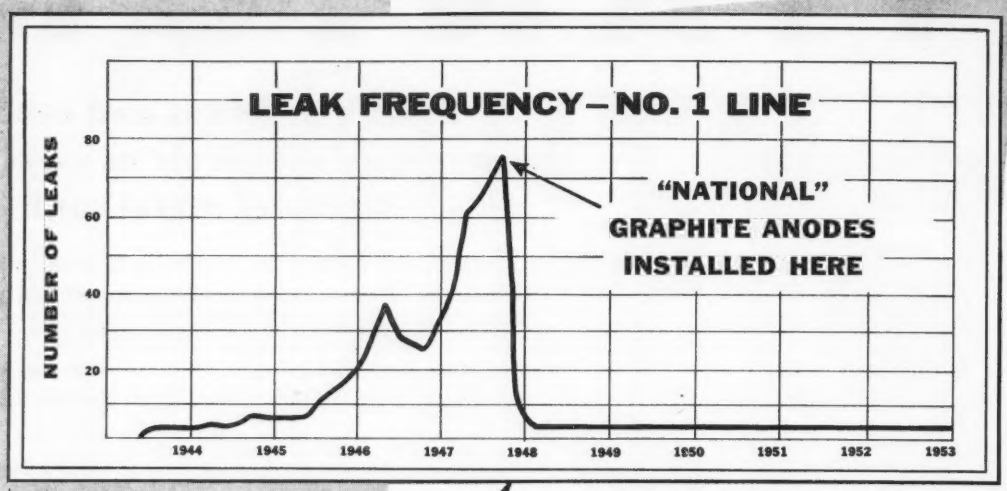
*Name*_____

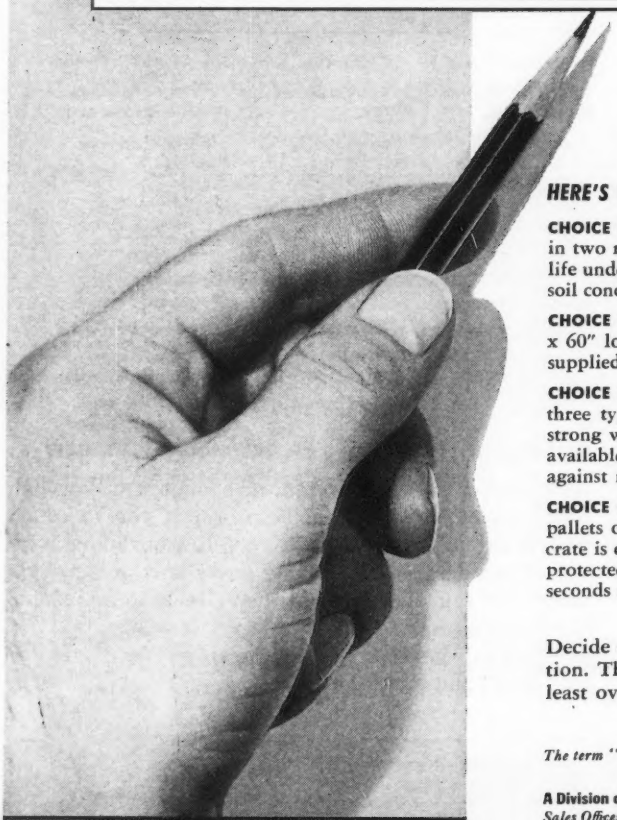
*Firm*_____ *Position*_____

*Address*_____

*City*_____ *State*_____

"ON COST AND SERVICE—YOU KNOW YOU'RE RIGHT WITH 'NATIONAL' GRAPHITE ANODES FOR CATHODIC PROTECTION"





● The superior efficiency and lower cost of cathodic protection by *impressed-current* have been demonstrated for many years. Once you have decided on an impressed-current system, be sure to consider these facts when buying anodes to do the job:

HERE'S WHY YOU SHOULD USE "NATIONAL" GRAPHITE ANODES

CHOICE OF MATERIAL: "National" Anodes are available from stock in two materials — *NA Graphite,* specially treated to give maximum life under all service conditions; *standard graphite,* where mildness of soil conditions indicates its use.

CHOICE OF SIZE: "National" Anodes are stocked in two sizes—3" dia. x 60" long and 4" dia. x 80" long. Special sizes and shapes can be supplied.

CHOICE OF LEADS: "National" Anodes are supplied with a choice of three types of cables—waterproof, oil-resistant waterproof or extra-strong waterproof. The standard anode-to-lead connection is the best available, capable of withstanding a 400-pound pull and sealed against moisture.

CHOICE OF SHIPMENT: 3" x 60" anodes are shipped in crates of five, pallets of seventy-five or loose in carload lots. The five-piece anode crate is designed for easy carrying by two men. The anodes are fully protected by sturdy wooden slats, steel-banded, yet are available in seconds at the point of use.

Decide on the sure, safe, economical *method* of cathodic protection. Then choose "National" Anodes to do the best job at the least overall cost.

Write for Catalog Section S-6500

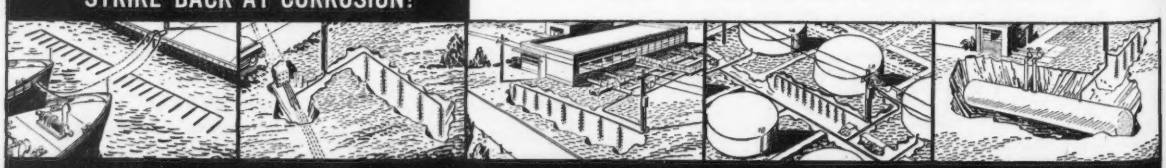
The term "National" is a registered trade-mark of Union Carbide and Carbon Corporation

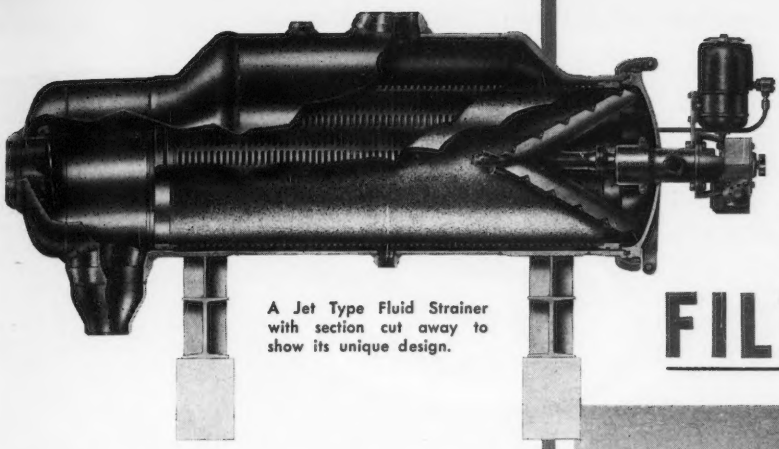
NATIONAL CARBON COMPANY

A Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y.

Sales Offices: Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco • *In Canada:* Union Carbide Canada Limited, Toronto

STRIKE BACK AT CORROSION!



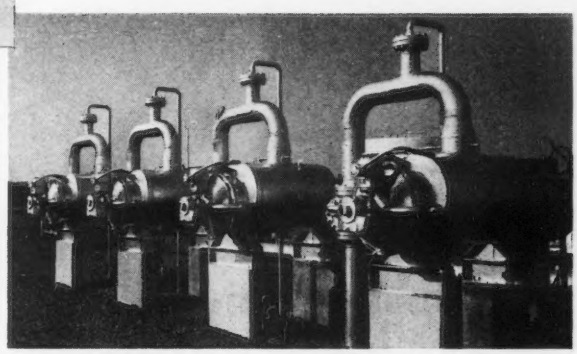


A Jet Type Fluid Strainer with section cut away to show its unique design.

WHAT PRICE FILTRATION?

Let's examine two installations required to handle 60,000 bpd: One with conventional vertical sock type strainers of approximately 10 square feet of filter area each; the other with Jet Type Horizontal Strainers of approximately 30 square feet of filter area each.
Required: One square foot of filter area per 1,000 bbls. per day or a total of 60 square feet of filter area with **adequate** standby capacity to assure no by-passing, at any time, of dirty strainers, or pipeline shutdown time for cleaning strainers.

OBJECTIVE: To filter all the product, all the time.*



An installation of four, 30,000 bpd capacity Jet Type Strainers on a new products pipeline.

Active Strainers Required — 6
Standby Capacity Based On Time Required To Clean And Resume Service
?
Active Strainers Required — 2
Only Two Standby Strainers Required Because of Quick Cleaning

INSTALLATION REQUIREMENTS

1. Valves — 3 Per Strainer
2. Extensive Manifolding
3. Installation Labor — Maximum
4. Overhead Crane for Lifting Closure and Basket
5. Sump
6. No Recording Instruments

STRAINER MAINTENANCE

1. Cleaning — Remove Closure and Replace Felt Manually. (Two Men 30 Minutes, 1 Man-Hour)
2. New or Reconditioned Felt Required for Each Cleaning
3. Replacement of Collapsed Strainer Elements Due to Excessive Pressure
4. No Automatic Operation Possible

*The expense of complete filtration is more than justified by the prevention of damage to closely fitted mechanical devices necessary to the operation of a pipeline.

INSTALLATION REQUIREMENTS

1. Valves — 3 Per Strainer
2. Less Manifolding
3. Less Installation Labor
4. No Overhead Crane
5. Sump
6. Pressure Differential Recording Gauge to Assure Daily Record of Pipeline Operation.

STRAINER MAINTENANCE

1. Cleaning Accomplished By One Man in **Less Than 5 Minutes** Without Opening Strainer
2. Stainless Mesh Screen Lasts Indefinitely
3. Alarm System Prevents Damage to Strainer Element Due to Excessive Pressures
4. Can Be Made Fully Automatic

ADDITIONAL OPERATING ADVANTAGES OF JET STRAINERS

1. Stream can be cleaned to any desired degree — 100, 200, 325, or 400 mesh screens optional.
2. Can be made fully automatic for operation at remote station.
3. Greater Safety — Strainer is cleaned without opening, consequently workmen are not subjected to danger of fumes and fire.

THORNHILL CRAVER CO.
P. O. BOX 1184 HOUSTON, TEXAS

Johns-Manville TRANTEX *polyvinyl* TAPE

- speeds application
- lowers construction cost
- controls corrosion

On field welded joints of mill wrapped pipelines, Johns-Manville Trantex Tape provides an economical and practical way to control corrosion at such critical points.

Trantex is a durable plastic tape that sticks on contact—bonds tightly to the pipe. No heat or heavy equipment is needed in its application—it is easily applied by hand or by simple hand-operated devices. Many users find that Trantex Tape overcomes the problem of getting a uniform coating on welded field joints—speeds application . . . lowers job costs on both small and large diameter underground pipelines. For welded field joints or for repairing damage to enamel, Trantex provides a convenient coating that is economical to apply . . . gives lasting protection against corrosion.

J-M Asbestos Pipeline Felt—used successfully for over 50 years to protect enamel coating against all types of soil conditions—is used also as an outer wrap or shield to protect Trantex in rocky areas.

For further information about Trantex Tape and J-M Asbestos Pipeline Felt, write Special Industries Department, Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay Street, Toronto 1, Ontario.

PROPERTIES OF TRANTEX TAPE

	*V-10	**V-20
Dielectric Strength per mil thickness, Approx.	1,000 V	1,000 V
Insulation Resistance, greater than (ASTM-D-257-49)	100,000 megohms	100,000 megohms
Temperature Limit	200 F	200 F
Adhesion oz. per inch width	30	20
Tensile strength lbs. per inch	30	56
Elongation at Break	250%	300%

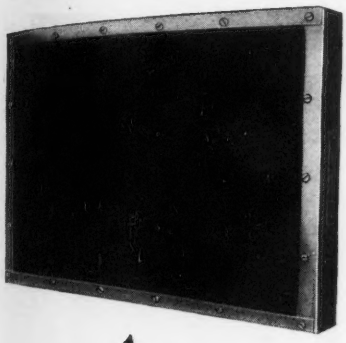
"Trantex" is a black polyvinyl tape. It is available in two thicknesses—

*V-10 is a 10 mil tape for average conditions, and
**V-20 is a 20 mil thickness for use where a more rugged coating is specified, such as to repair enamel coatings.

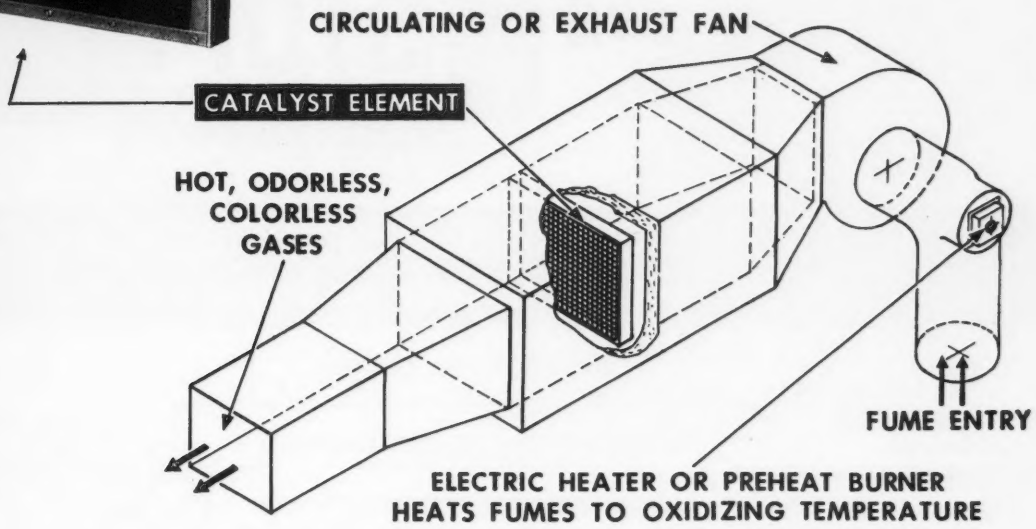
JOHNS-MANVILLE JM PRODUCTS

Johns-Manville TRANTEX *polyvinyl* TAPE

PROTECTS PIPELINES AGAINST CORROSION



Basic Elements of Fume Combustion System for eliminating odorous, poisonous, explosive or flammable fumes from industrial processes. The Catalytic Combustion Corp., Detroit, Mich., produces and installs systems that furnish useful heat for many operations . . . while routing smog, smells and noxious gases.



At temperatures up to 1500°F

Catalytic Combustion Units Using Nickel-Chromium Alloys

Operate Efficiently for Years

Scores of plant operators now liberate and use heat energy that, heretofore, went to waste . . .

And by the same means, these operators control air pollution and convert noxious or explosive fumes into odor-free harmless gases.

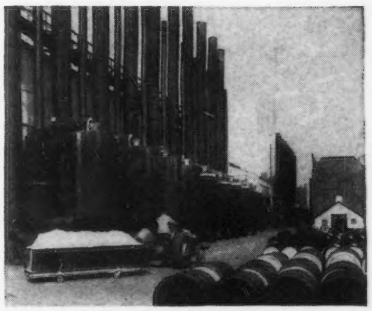
How? By catalytic oxidation on the industrial level. Thanks to a Catalytic Combustion Corporation development which utilizes the catalytic action of platinum and the heat-and-corrosion resistance of nickel-chromium alloys.

The drawing shows fundamentals of a catalytic fume combustion system, and the photograph shows a typical catalyst element, 18″ x 24″ x 2⅝″, weighing about 30 pounds.

The latter comprises a frame of 18-8 chromium-nickel stainless steel, and 16-mesh screen of 60-16 nickel-chromium alloy (ACI Type "HW"), containing mat of this alloy in the form of ribbon . . . two miles of it . . . 1/16″ wide. Deposited on this mat is the catalytic medium, vital metallic platinum.

Screens and mat of the 60-16 nickel-chromium alloy resist both heat and corrosion to an extent that assures long life and efficiency at temperatures up to 1500°F. Moreover, thermal expansivity of the alloy is close enough to that of platinum to prevent spalling or flaking of the catalyst.

Hourly, the 2-mile alloy ribbon mat with its catalytic agent can handle up to 3000 pounds of most gases, and liberate heat at rates up to 800,000 B.T.U.



Large Installation of Catalytic Combustion Units . . used to decompose irritating exhaust gases from production of phthalic anhydride at Detroit plant of Reichhold Chemicals Co. It comprises these two batteries of 10 units each, and eight similar units, not shown. Each incinerator processes 1200 cu. ft. of gas per minute, 24 hours daily. Ten initially installed in 1949 have now given more than 30,000 hours' service with no catalyst replacement.

Nickel alloys may help you, too, improve your products or equipment. Whenever you face a metal problem, send us the details for our suggestions.

INCO TRADE MARK

THE INTERNATIONAL NICKEL COMPANY, INC. 67 Wall Street New York 5, N.Y.

STOP PIPE-LINE SHUTDOWNS

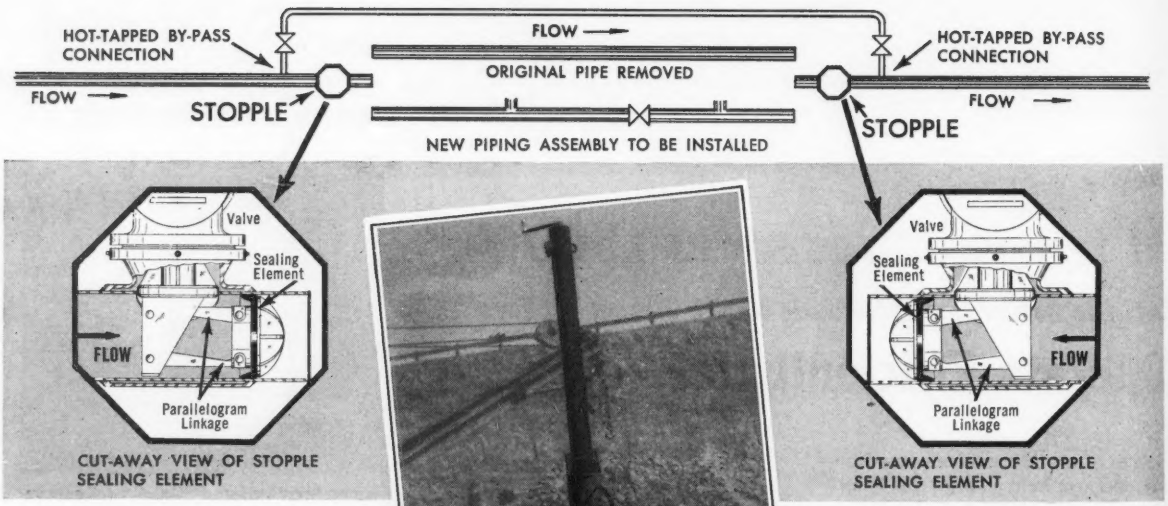
with the WILLIAMSON **STOPPLE**

T. D. WILLIAMSON, INC. TULSA, U. S. A.

CONTINUE TO OPERATE THROUGH A BY-PASS

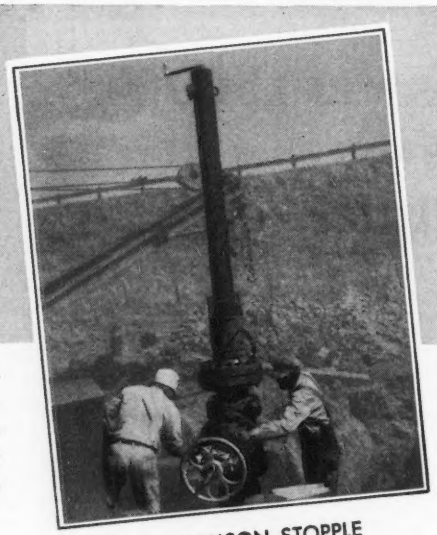
While making repairs or additions . . .

TYPICAL PIPING CHANGE



Experienced Williamson representatives, factory-trained engineers, are on hand to offer you their assistance in the proper use and installation of Williamson STOPPLES.

STOPPLES are available for purchase or rental with purchase option.



WILLIAMSON STOPPLE

HOLDS PRESSURES UP TO 1,000 PSI DEPENDING UPON PIPE SIZE, WALL THICKNESS AND CONDITION.

STOPPLE SIZES NOW AVAILABLE*			
4″	6″	8″	12″
	16″	20″	

STOPPLE SIZES IN PRODUCTION			
10″	14″	18″	22″

*Allow 2 to 4 weeks for assembly of accessory parts. Stopple stock subject to prior sale.

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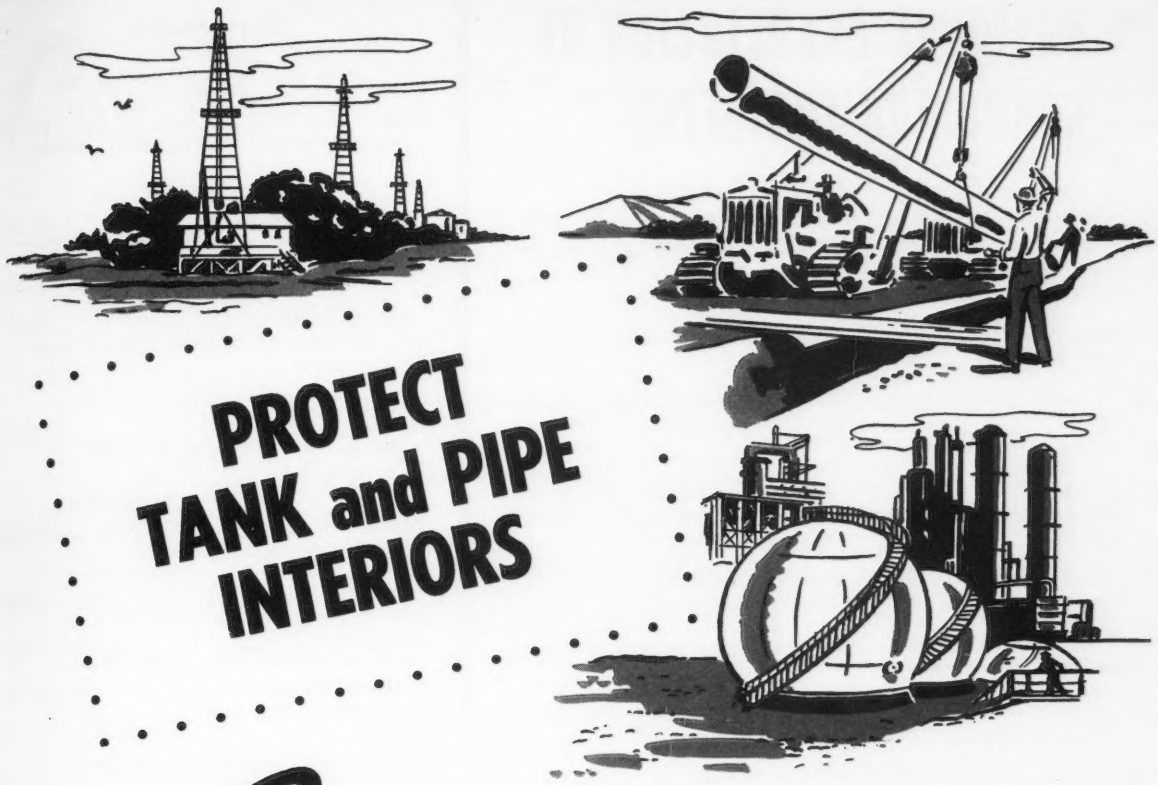

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(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

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Corrosion

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Topic of the Month

A Technique for Installing Carbon Anodes in Cable Ducts

By EDWARD J. DOYLE*

PUBLIC UTILITIES operating in urban areas have not made extensive use of cathodic protection of their underground cables until recent years. In the past, these urban areas were saturated with stray direct currents from various sources and bonding at appropriate locations usually corrected unsatisfactory voltage conditions. At the same time these stray currents actually provided cathodic protection at other locations where the currents entered the cables. Further, when attempting the use of cathodic protection in these areas, the problems of interference to other structures are usually quite complex. For this reason when cathodic protection is used, the anodes are often placed in ducts adjacent to the cables being protected. The use of such duct anodes confines the protection currents to a small area in or near the duct bank and rarely endangers other structures.

In early installations the use of scrap lead cable as an anode was attempted, but it was found that the thin lead sheath was sacrificed too rapidly and the remains of the cable became frozen in the duct by the corrosion product. A special lead anode cable consisting of a thick layer of lead over a steel strand was then devised. It was found that with normal protection currents, these lead anode cables would last for four or five years before they required replacement. Such lead anode cables have been used in moderate numbers for the past 20 years.

As electric trolley systems have been replaced by motor buses in recent years, the necessity of using cathodic protection in these urban areas increased greatly. The use of materials other than lead for duct anodes was studied. Because of the objection to the short time replacement necessary with lead anodes, the use of a longer lasting material, such as graphite was felt appropriate. Several types of graphite anodes were then developed for duct use, one of which was installed in Manchester, New Hampshire, by the New England Telephone and Telegraph Company in the fall of 1954.

The type of anode used in the Manchester trial consisted of a carbon rod 18 inches in length and 2 inches in diameter. A stranded rubber and neoprene insulated wire runs through the anode, projecting from both ends and connected electrically and mechanically in-

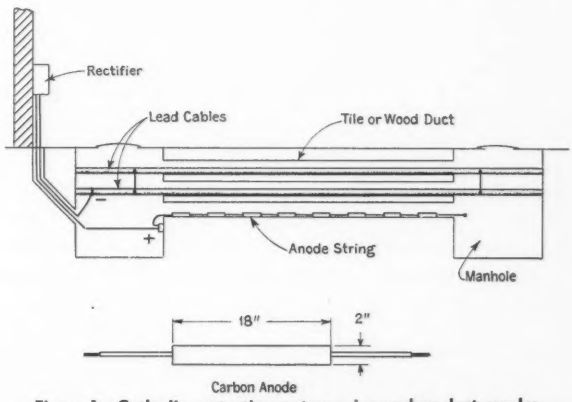

Figure 1—Cathodic protection system using carbon duct anodes.

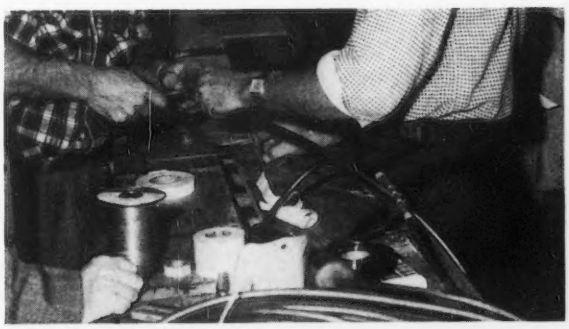

Figure 2—Splicing the anodes on a stranded insulated wire.

* Engineer, American Telephone and Telegraph Company, New York.

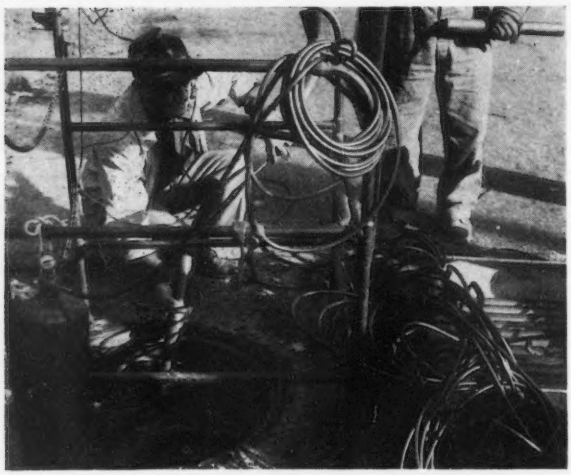

Figure 3—Installing the anode string. A man in the hole guides the anodes into the duct as they are pulled from the other end of the run.

ternally. In order to protect a length of duct run, the individual anodes are spliced end to end like sausages on a string. They are then pulled into the duct opposite the point being protected and the protective current applied to the end of the anode string in the manhole at one end of the duct run. Figure 1 shows a typical application of such a string of anodes with an enlarged view of a single anode.

In assembling the anodes, the characteristic of the splice used to connect them is of extreme importance. It must be mechanically strong, because as the anodes are pulled into the duct the full tension is borne by it. The splice also must be perfectly insulated, for any leakage current to ground would quickly corrode the wire, isolate the anodes from their current supply and possibly hinder their removal from the duct. For the Manchester trial a crimped sleeve splice able to withstand tensions of about 800 pounds was developed. The splice was covered with a double half-lapped layer of soft rubber tape to make it watertight and a double half-lapped layer of polyvinyl chloride tape for abrasion resistance.

At the Manchester trial the anodes were spliced into a string at a near-by telephone company garage and the completed string carried to the job. It was found that the string of anodes could be pulled into a duct with comparative ease, once the duct had been rodded out to clear any split. After installation, voltage reduction tests indicated that adequate protection was being given to the other cables in the duct run, with only moderate amounts of current. Figures 2 and 3 show the splicing ant installation work at the trial.

The results of the Manchester trial indicate that carbon duct anodes show promise of becoming an important tool in cathodic protection work in urban areas. Their installation is quite simple and the small electrical field lessens danger of interference to other structures. Most important of all, the life of these anodes should be much longer than that of other materials used for duct anodes heretofore.

Use of High Molecular Weight Corrosion Inhibitors In Petroleum Refineries*

By H. HOWARD BENNETT

Introduction

THE PETROLEUM refining industry, like others, always has been faced with corrosion problems for which there are few satisfactory solutions. The recent development and use of high molecular weight organic film-forming type corrosion inhibitors has supplied an answer to several of these problems.

The mechanism by which these inhibitors function to prevent corrosion has been established reasonably well. Considerable evidence, both theoretical and experimental supports the belief that these inhibitors function by being adsorbed on a metal surface to form a well-organized and oriented film.

The most economical corrosion protection from an inhibitor is obtained when an optimum balance is achieved between corrosion reduction and inhibitor cost. Some of the factors influencing inhibitor performance that should be taken into consideration are:

1) inhibitor concentration,
2) inhibitor solubility in the different phases in the system,
3) pH or acidity of the corrosive environment,
4) nature of the corrosive,
5) temperature,
6) velocity of fluids past protected surfaces, and
7) other conditions.

In order to evaluate these factors it is desirable to have a quick and accurate method of determining corrosion rates in an operating unit because laboratory evaluation of an inhibitor frequently gives results quite different from those actually obtained in a process unit.

An evaluation procedure will be discussed that was used on a crude distillation unit to determine the efficiency of an inhibitor at two concentrations and several pH levels. Inhibitors also have been tested in other units to evaluate their ability to control various types of corrosion and determine the degree of other benefits. Experience resulting from the use of inhibitors to control corrosion and fouling in crude units, alkylation units, gas plants, cracking units and other refinery processes will be discussed.

How An Inhibitor Works

Corrosion of metal normally is considered to be electrochemical in nature, during which process metals replace ions in the corrosive solution.[1] Considerable evidence points to the fact that the surface of a metal is covered with numerous anodic and cathodic areas. This condition leads to the formation of local cells between the anodes and cathodes. These cells are responsible for the corrosion that occurs.

★ A paper presented at the Tenth Annual Conference, National Association of Corrosion Engineers, Kansas City, Mo., March 15-19, 1954.

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Abstract

The theory of adsorbtive inhibitors is discussed briefly. An account is given of tests by coupons and in refinery equipment evaluating the effect of three semi-polar compounds in reducing the corrosion of refinery equipment. Data on concentrations, technique of additions to streams, coincident use of ammonia, cost per barrel of charge, percentages discharged in effluent and percentage retained in stream are given. Considerable information is revealed indicating the detergent action of the inhibitors assists in reducing deposits on tubes and in pumps and other equipment and thereby extends the period between shutdowns for cleaning. Significant reductions in the corrosion rates in crude distillation units, steam reboilers, straight run deisobutanizers, vacuum pumps, alkylation units, TCC units and other refinery equipment are reported. The author concludes water soluble inhibitors tested are sufficiently soluble in hydrocarbons to provide corrosion protection.

The high molecular weight organic inhibitors are believed to form an adsorbed and well oriented molecular layer on metal surfaces which interferes with the corrosion process.[2] The polar part of the molecule attaches itself firmly to the metal surface and prevents corrosion of the portion covered. The balance of the large molecule normally is directed away from the surface and interferes with the corrosive action by some sort of barrier action.[3]

Data reported by Nathan[4] indicates that the effectiveness of an inhibitor is related to the length of the molecule and the closeness with which the molecules are packed in the barrier, the latter being a function of inhibitor concentration.

Ch'iao and Mann[5] found that except at very low concentrations, inhibitor efficiency was proportional to concentration and followed Lamgmuir's equation for mono-molecular adsorbed films. Organic inhibitor concentrations used in the petroleum refining industry are of the order of 3 to 15 ppm at which levels the efficiencies are far above those predicted by Lamgmuir's equation. The inhibitors appear to be adsorbed so strongly on a surface that they plate out

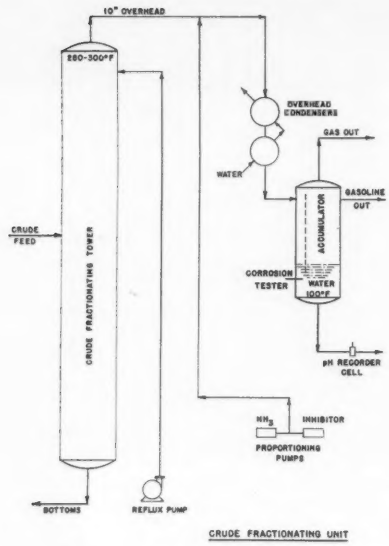

Figure 1—Crude fractionating unit.

TABLE 1—Selected Properties of Crudes Processed

	Gravity	Percent Sulfur	Salt Content Lb./1000 Bbl.
Kuwait	31.0	2.3	20.0
Iraq	35.0	1.9	19.0

almost quantitatively from streams containing extremely low concentrations, until an unbroken film is established. This fact probably explains the failure of conventional formulas to predict the behavior of these inhibitors. It also may account for their strong detergent action. After the film is established the concentration in the stream need only be sufficient to maintain the film in repair; however, the degree of repair can be affected by the turbulence of the stream containing the inhibitor.

It has not been possible to accurately predict inhibitor efficiency from fundamental data or obtain good correlation between laboratory and process units, consequently, most of the information available on the organic film-forming inhibitors is data obtained from process units.

Crude Unit Test

A test run to determine the amount of protection afforded by a water soluble high molecular weight organic semi-polar compound (Inhibitor A*) was conducted on a single stage crude distillation unit. The test was arranged so that the effectiveness of the inhibitor was determined for different pH values at two different inhibitor concentrations. Each test period was approximately two weeks in duration. The pH of the water phase in the system was adjusted by the addition of aqueous ammonia. Values obtained from a pH recorder were used as the basis for regulating the ammonia addition. During the run there was no indication that the inhibitor caused any mal-functioning of the pH cell. Daily laboratory analyses were

* Polyexyethylated glycol ether derivative of dehydroabietylamine.

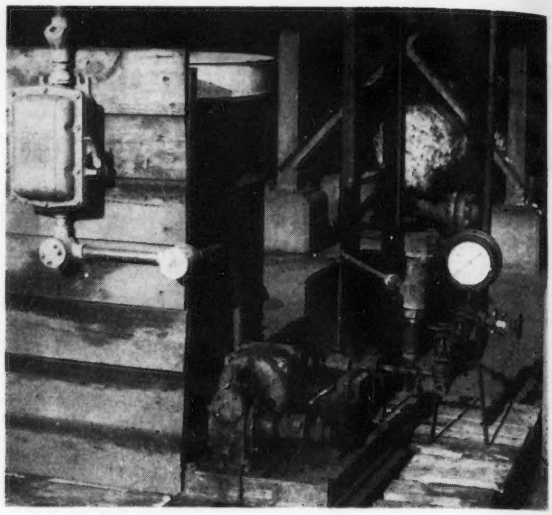

Figure 2—Inhibitor injection equipment.

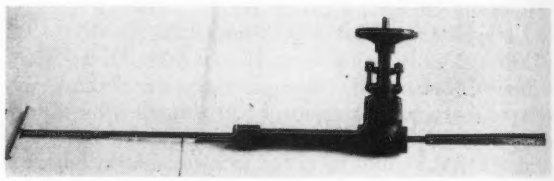

Figure 3—Removable corrosion test coupon holder.

made of the effluent water for pH and total iron content. The effluent water also was analyzed several times for inhibitor content. To determine actual corrosion rates steel corrosion test coupons were used.

Figure 1 shows a schematic flow diagram of the part of the system to which the inhibitor was added during the test. The tower operates at about 5 psig with a tower top temperature of about 280 F. The overhead product was a 400 F endpoint straight run gasoline. The unit charge was 8000 barrels of crude which produced an overhead stream of 2500 barrels of gasoline and 170 barrels of water per day. The gas produced contained from 0.3 to 0.75 volume percent of hydrogen sulfide.

Two crudes were processed during the test runs. Table 1 lists the properties of the crudes processed that might influence low temperature corrosion.

The overhead product is condensed by two series connected shell and tube condensers. The shells are monel clad and the exchanger tubes are Admiralty.

The condensed gasoline and water from the exchangers is carried through a steel rundown line to a separator where the water is separated from the gasoline. In this vessel the gas also is separated from the gasoline and vented overhead to the refinery gas system. The water is drawn off to the sewer and the gasoline is pumped to storage. The cell of the recording pH meter is located on this water draw system.

The ammonia and the inhibitor were injected into the tower overhead vapor line near the tower. Proportioning pumps of the type shown Figure 2 were

used to add both the inhibitor and the 14 degree Baume aqueous ammonia. The inhibitor was injected as a 2 to 5 percent solution in water. The two solutions were pumped into a common line which carried the materials to the injection point in the system.

During the tests the inhibitor concentrations used were 4.5 and 9.0 ppm based on the total overhead from the fractionating tower. Based on the crude charge to the unit the cost per barrel was 0.15 mils and 0.3 mils respectively for the two concentrations. The ammonia required to maintain a 7.8 pH in the system (a value considered to be optimum) based on the same crude charge was 0.45 mils per barrel.

The device shown in Figure 3 was constructed so that corrosion test coupons could be introduced into and removed from the system without interrupting the operation. The test coupons were 16 gauge SAE 1020 steel measuring 0.75 x 10.4 inches which provided a square decimeter of exposed surface for each specimen. The coupons were cleaned with fine emery cloth before weighing prior to exposure. After exposure they were cleaned with soap and water using a stiff bristled brush. This cleaning was adequate due to absence of any hard adhering corrosion products. Two coupons were exposed during each test and the average values used. The weight loss on the simultaneously exposed samples was in good agreement, with the maximum deviation less than 5 percent.

Results obtained from the test coupons are shown in Figure 4 in which the corrosion rate of the steel, in inches per year penetration, are plotted on a logarithmic scale against the pH of the system. The curves for two inhibitor concentrations are shown. They are almost parallel, indicating that the reduction in corrosion for the range tested, is proportional to the inhibitor concentration regardless of the pH. The corrosion at the higher inhibitor concentration averages about 66 percent less than the corrosion at the lower concentration. The maximum corrosion shown at the lowest pH at 9 ppm inhibitor concentration was less than .065 inches per year. The corrosion rate at 5 pH was .015 inches per year, a value that represents an acceptable corrosion rate for such equipment.

Figure 5 gives similar curves showing the effect of the inhibitor on the iron content of the water in the system. These curves also are nearly parallel. The higher inhibitor concentration effected a reduction in iron content over the lower concentration. However, the reduction in iron content is not as pronounced as the reduction in corrosion rate shown by the test coupons. The average reduction in iron content was roughly 20 percent versus the 66 percent reduction in corrosion shown by the coupons.

There are 400 square feet of ferrous surface in the system downstream from the point of inhibitor injec-

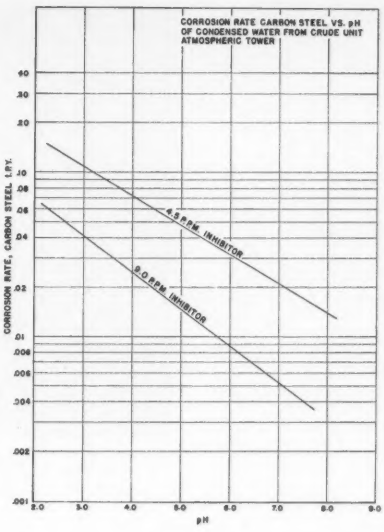
CORROSION RATE CARBON STEEL VS. pH OF CONDENSED WATER FROM CRUDE UNIT ATMOSPHERIC TOWER
CORROSION RATE, CARBON STEEL I.P.Y.
4.5 P.P.M. INHIBITOR
9.0 P.P.M. INHIBITOR
pH

Figure 4

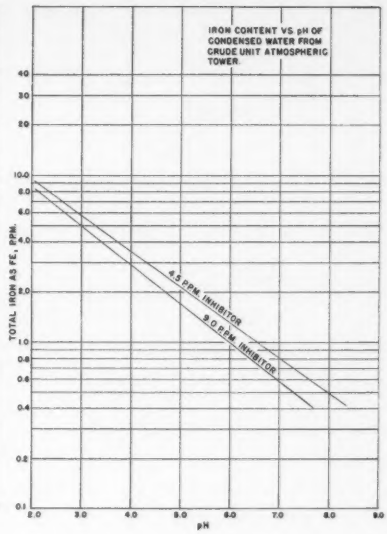
IRON CONTENT VS. pH OF CONDENSED WATER FROM CRUDE UNIT ATMOSPHERIC TOWER
TOTAL IRON AS FE, PPM.
4.5 P.P.M. INHIBITOR
9.0 P.P.M. INHIBITOR
pH

Figure 5

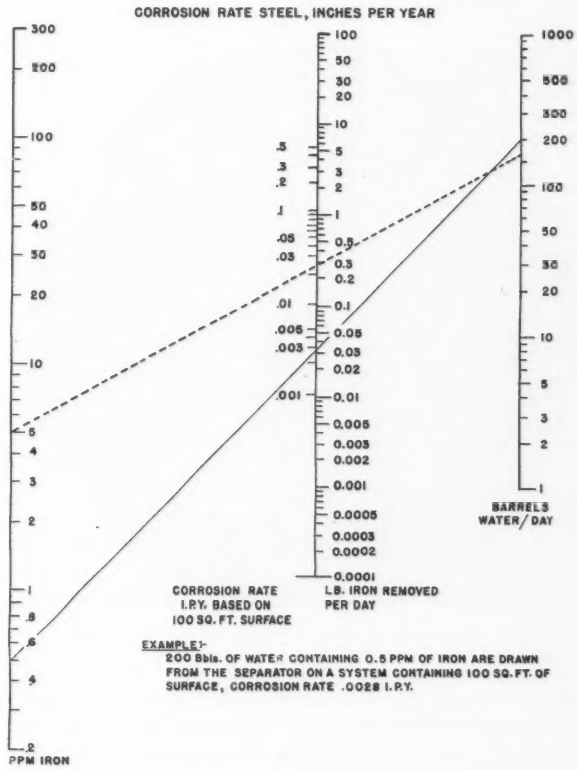
CORROSION RATE STEEL, INCHES PER YEAR
PPM IRON
CORROSION RATE I.P.Y. BASED ON 100 SQ. FT. SURFACE
LB. IRON REMOVED PER DAY
BARRELS WATER/DAY
EXAMPLE:-
200 Bbls. OF WATER CONTAINING 0.5 PPM OF IRON ARE DRAWN FROM THE SEPARATOR ON A SYSTEM CONTAINING 100 SQ. FT. OF SURFACE, CORROSION RATE .0028 I.P.Y.

Figure 6—Corrosion rate nomograph.

TABLE 2
Distribution of Inhibitor in Overhead Stream at 4.5 ppm Concentration

	Water	Gasoline
Stream composition, percentage	6.4	93.6
Inhibitor concentration ppm	19.0	3.5
Percentage of total inhibitor	27.5	72.5

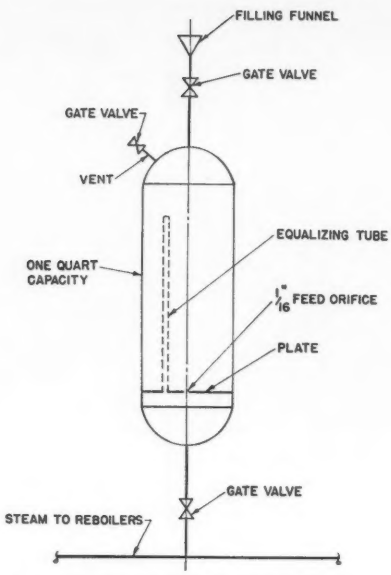

Figure 7—Vessel used for inhibitor addition.

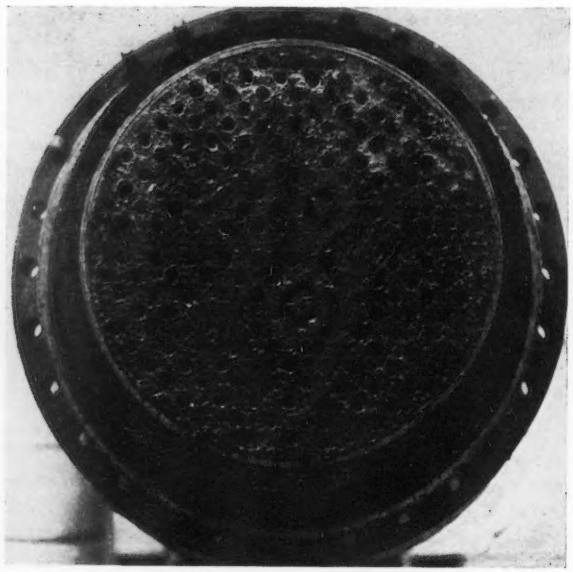

Figure 8—Iron corrosion deposits on exchanger tube sheet.

tion. Much of this surface is either at temperatures above the condensation point of water or, in case of the separator, is only wetted with gasoline. Under these conditions it is improbable that corrosion takes place, or that the corrosion products get into the water stream. A conservative estimate of the actual surface in the system exposed to active corrosion is about 140 square feet.

Using the nomograph shown in Figure 6 to calculate the corrosion rate from the iron content of the effluent water at 3 pH and 9 ppm of inhibitor, a rate of 0.023 ipy per 100 square feet of surface results. This rate can be corrected for 140 square feet of surface by using the following formula:

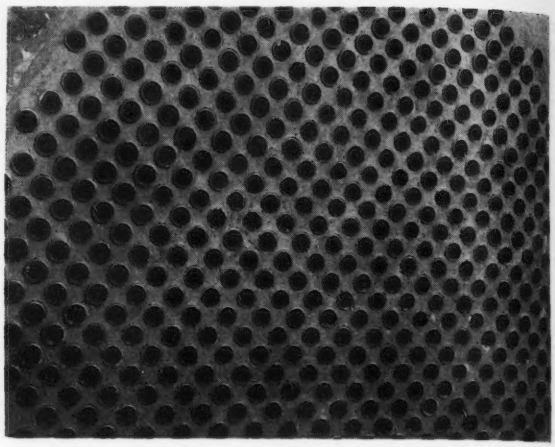

Figure 9—Exchanger tube sheet after using inhibitor.

$$\frac{100}{A} \times R' = R$$

A = area in square feet of system exposed to corrosive fluid.
R′ = rate in ipy for 100 square feet of surface.
R = rate for area of A square feet.

When this is done the rate indicated by the iron content of the water is .016 ipy. Corrosion test coupons exposed under the same conditions indicated .042 ipy corrosion rate. This indicates a wide difference in corrosion rates derived by the two methods.

Distribution of a water soluble inhibitor between the water and hydrocarbon phases in system of this nature has been largely a matter of speculation. Test run data permitted the calculation of the distribution of the inhibitor between the gasoline and the water. The results from the information obtained are shown in Table 2.

These values were calculated from several analyses of the effluent water for inhibitor content, made after the system had reached equilibrium. The inhibitor content in the gasoline was calculated from the difference between the amount added and that found in the water. It will be noted that although the concentration of the inhibitor in the water layer is relatively high, it contains only a small percentage of the total inhibitor. The gasoline still contains 72.5 percent of the added inhibitor, or 3.5 ppm. This is sufficient to provide adequate protection to other equipment through which the gasoline must pass.

The results of this test show that the particular film-forming organic inhibitor tested can reduce materially the corrosion of steel in this type of service. Some detergent action was evidenced by a 10 percent increase in the heat transfer coefficients on the exchangers during the test which indicates that such action may be beneficial. To obtain optimum results the use of some ammonia with the inhibitor may be desirable.

Iron analyses of effluent water stream can be misleading as to corrosion rates. Properly located corrosion test coupons can provide a satisfactory method

of determining corrosion rates. The distribution of this water soluble inhibitor when used on a crude unit was such that enough remained in the hydrocarbon stream to provide continued protection.

Steam Reboiler Corrosion

Interior corrosion of the lower portion of the steel tubes in steam heated vertical reboilers on towers has been very troublesome. The corrosion occurs on the steam side in the form of severe pitting accompanied by a general loss of metal. Rates as high as 1/16 ipy have been experienced. Various methods of reducing this corrosion have been tried with little success. It was decided to add a water dispersible high molecular weight semi-polar compound (Inhibitor B*) to the steam supplying twin reboilers on a deisobutanizer tower, which have been a chronic source of trouble. The reboilers operate at 250 F, heated by approximately 500,000 pounds per day of 45 psig steam.

Figure 7 shows the inhibitor injection installation. This consisted of a one quart capacity pot with the valves necessary to add the inhibitor. A quart of inhibitor is added daily to the pot and allowed to drip into the steam to the reboiler. After eleven months of operation the reboilers were inspected and found to be in excellent condition. The lower ends of the tubes were found to be entirely free of the black iron oxide deposits usually found when corrosion is taking place. Figure 8 shows the tubes as they appear when corrosion is occurring. The iron oxide deposits are clearly visible at the end of the tubes. Figure 9 shows the condition of the tubes at the time they were inspected after eleven months of operation. There was no iron oxide at the ends of the tubes and there was no evidence of corrosion. No reduction in heat transfer rates occurred during the run nor have any undesirable effects been noted.

Without the inhibitor maintenance costs on these exchangers has averaged approximately $3000 a year. This does not take into consideration the losses caused by the off-stream time of the unit. The inhibitor is being added to the steam at a cost of less than $200 a year. Present indications are that the life of these reboilers will be extended from two to three times by the use of the inhibitor.

Straight Run Deisobutanizer

Severe corrosion occurred in the straight run deisobutanizer unit in a West Coast refinery** from the time it was placed in service. Figure 10 shows a schematic flow diagram of the unit. Shutdowns were required every two or three months for replacement of equipment. Part of the charge to the unit was butanes from the alkylation unit. At times, these butanes contained traces of organic fluorides which decomposed to produce hydrofluoric acid. The acid dissolved in the 10 to 15 gallons of water per day in the overhead stream producing pH values as low as 2.4 in the accumulator effluent water.

Treatment with a water soluble high molecular weight semi-polar compound (Inhibitor A) was started in October, 1952. A 5 percent solution of inhibitor in water was injected continuously into the tower overhead stream at a rate to provide a concentration of 3 ppm in the total overhead (product plus reflux). In order to improve the effectiveness of the inhibitors one quart of 25 degree Baume sodium hydroxide was added to each 30 gallons of the inhibitor solution. This raised the pH to between 5.0 and 6.0. The effect of the use of the caustic on the iron content of the water is shown in Table 3.

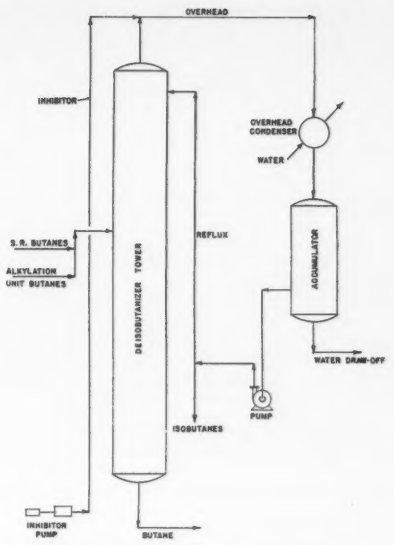

Figure 10—Straight run deisobutanizer.

TABLE 3—Effect of Caustic on Iron Content

DATE	Inhibitor ppm	NaOH ppm	Iron ppm	pH
10- 6-52	3.0	0.0	1.20	4.6
10-13-52	3.0	0.0	0.82	5.2
10-22-52	3.0	0.0	1.24	4.8
11-12-52	3.0	0.0	0.89	5.2
12-18-52	3.0	0.0	0.94	5.1
1- 6-53	3.0	0.37	0.22	5.5
1- 8-53	3.0	0.37	0.34	5.6
1- 9-53	3.0	0.37	0.34	5.1
1-11-53	3.0	0.37	0.4	5.3

The addition of this small amount of caustic soda reduced the iron in the effluent water by a significant amount. The iron content of the water appears to be a good criterion of the effectiveness of the inhibitor for this type of corrosion. The use of the inhibitor and neutralizing agent has reduced the need for repairs and has alleviated a very annoying condition in this unit. The conventional solution to this problem would have required the use of Monel, a metal on the critical list. The inhibitor protection has been accomplished at a cost of 0.4 mils per barrel of charge to the unit.

Furfural Vacuum Pumps

In refining a lubricating oil with furfural the final stripping of the raffinate and extract is performed in towers under vacuum. The vacuum is maintained by reciprocating vacuum pumps. After short periods of operation the pumps failed to maintain the desired vacuum due to fouled valves and sticking piston rings. Consequently, frequent repairs were required

* A semi-polar high molecular weight compound of the imidazoline type.

** Torrance refinery of the General Petroleum Corp., affiliate of the Socony-Vacuum Oil Co., Inc.

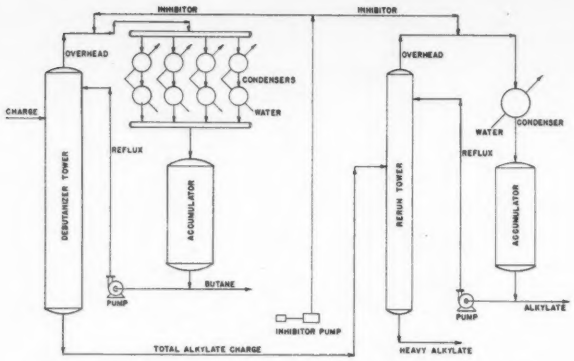

Figure 11—Debutanizer and rerun towers of HF alkylation unit.

to keep them operating satisfactorily. This condition appeared to result partly from corrosion and partly from organic materials which acted as a binder for the corrosion products.

Since the film-forming inhibitors have been found to reduce corrosion and also act as detergents, it appeared that they might be a solution to this problem. Accordingly, two percent by volume of an oil soluble high molecular weight semi-polar compound (Inhibitor C*) was added to a suitable solvent and injected into the vacuum cylinder. The inhibitor consumption was less than one-half pint per cylinder per week.

The pumps were inspected after six months' operation and found to be in good condition. The piston rings which had required replacement every three months were free in the grooves and in good condition. The valves which had required reconditioning every two months were clean and in good operating condition. These pumps have now operated nine months with no evidence of the difficulties formerly experienced. It is estimated that maintenance has been reduced to one-fifth of what it was before the inhibitor was added to the oil.

Alkylation Unit

Severe corrosion was occurring in the debutanizer and alkylation rerun towers in a West Coast refinery.** The corrosion was in overhead condensers, rundown piping, accumulators and reflux pumps, resulting in frequent replacement of these items. The corrosion was caused by a weak hydrofluoric acid solution formed by the hydrolysis of traces of organic fluorides in the charge to the towers.

In an effort to control this corrosion, the injection of an oil soluble high molecular weight organic semi-polar compound (Inhibitor C), was started into the overhead vapor lines on both the debutanizer tower and the alkylate rerun tower in July, 1952. Figure 11 shows a schematic flow diagram of the part of the unit where the inhibitor was injected.

The inhibitor was mixed with light alkylate to form a 25 percent solution of inhibitor and pumped batchwise from the mixing drum into the tower overhead streams. The addition to each tower was made over a three hour period once a shift. For the first week the rate was one gallon of inhibitor per thousand barrels per day of total overhead. After the first week the rate was reduced to one-half gallon per thousand barrels or a concentration of 12 ppm.

The injection of alkaline cooling tower water into the overhead streams was continued in sufficient amounts to maintain an accumulator pH of 8.5. This practice of injecting alkaline cooling tower water into the stream ahead of the condensers has been used for a number of years to relieve a chronic plugging condition in the overhead condensers.

Since starting the use of the inhibitor a soft white siliceous material has been deposited in the overhead condensers of the debutanizer tower. The formation of this material may be connected in no way with the use of the inhibitor because several operational changes have been made since the injection of the inhibitor was started. The deposit is very easily removed and presents no difficulty other than an operation interruption during its removal. When the loss of reflux becomes apparent, tower reflux is reduced and a bank of condensers is by-passed for cleaning.

The reduction in corrosion rates was marked. The debutanizer reflux accumulator corrosion was reduced by one-third and on the rundown lines the rate dropped from 1.0 ipy to .08 ipy, a reduction of 92 percent. The reflux pumps which were requiring replacement every three months have continued in operation.

The effectiveness of the use of the inhibitor was immediately evidenced by the cessation of reflux pump and rundown line failures. Comparing periods before and after the use of the inhibitor, maintenance costs while using the inhibitor were only one-sixth as much as those experienced without the inhibitor. The inhibitor cost is about 1.5 mils per barrel on the rated capacity of the unit.

The inhibitor carryover with the product is small and no contamination of product or effect on product specification has been noted.

TCC Units

High molecular weight film-forming inhibitors of different types have been used for approximately two years to control corrosion and fouling in the overhead condensing system on TCC units. They are injected into the tower overhead vapor line ahead of the condensers. The inhibitor is diluted with a suitable solvent to facilitate handling and introduced with either a chemical proportioning pump or by metering it from a pressured tank. The amount used varies from 3 to 5 ppm of the total overhead from the fractionating tower. The cost of the inhibitor is from 0.4 to 0.7 mils per barrel of unit charge.

While it has been impossible to establish the reduction in corrosion rates on actual equipment, corrosion test coupons exposed in the system while using an inhibitor have shown a 50 percent reduction in the corrosion rate for Admiralty metal, which is used for condenser tubes. A typical analysis of the separator effluent water shows the pH to be 8.4 and the iron content 0.7 ppm.

The overhead product to the condensers is a 400 F endpoint gasoline that contains about 5 percent water. The product is essentially free of chlorides but con-

* Imidazoline type.
** Torrance refinery.

tains a fairly high percentage of hydrogen sulfide. The pH of the effluent water is about 8.2 and does not require the addition of ammonia.

The appearance of the condensers after Inhibitor A had been used for nine months is shown in Figure 12. This is typical for all condensers in this service when the high molecular weight film-forming inhibitors are used. Photographs are not available to show the condition of the condensers before the addition of an inhibitor, however, they usually were found to be severely fouled with a high percentage of the spaces between the tubes bridged with corrosion products.

The clean condition of the condensers resulting from reduced corrosion and the detergent action of the inhibitor has improved heat transfer coefficients and drastically reduced cleaning costs on the condenser bundles. The small amount of scale found in the bundles is soft and easily removed by a water flush.

No adverse effect on product quality has been noted.

Present indications are that the life of Admiralty bundles will be doubled while these inhibitors are used.

Figure 12—TCC unit fractionating tower overhead condense bundle.

Crude Unit Protection

A water soluble high molecular weight organic semi-polar compound (Inhibitor A) has been used since May 1952 on a crude unit processing 14,000 barrels a day of a mixed Texas crude containing 20 pounds per 1000 barrels of salt and about 0.6 percent sulfur. Initial use of the compound was to relieve a severely fouled overhead condensing system which was causing back pressure on the atmospheric tower. Shortly after the inhibitor was started to the system, this condition was relieved and after two months, when the bundles were inspected, they were found to be clean. When the condensers and the tower were examined again after twelve months, they were found to be only moderately dirty and were readily cleaned by flushing with water. These condensers which previously had become so fouled with corrosion products that they were removed from the unit for mechanical cleaning at six month intervals, have not required such cleaning in the 22 months since the use of the inhibitor was started. In addition there has been no cleaning of the towers or vessels in this period. The condensers which previously had a two year life have required no repairs in 20 months of service.

The inhibitor is mixed with water and added once a day to the vapor leaving the tower at a rate to provide 5 ppm in the total overhead. Enough ammonia is added to the system to maintain a 7.0 pH on the effluent water. This reduction in corrosion and fouling is being accomplished at an inhibitor cost of about 0.3 mils per barrel of crude charge. Similar results are being obtained with this inhibitor on other crude units.

Gas Recovery Plant

In a gas recovery plant the lean to fat absorption oil exchangers became fouled with corrosion products and required a shutdown and cleanout every two months. A schematic flow diagram of the unit is shown in Figure 13. The adsorption oil (kerosene) is

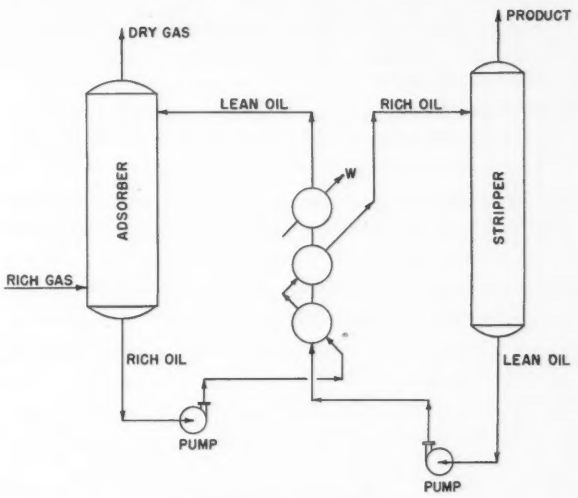

Figure 13—Gas recovery plant.

contacted with the gases from all units and tanks in the refinery to recover the usable light hydrocarbons. These gases contain hydrogen sulfide and other corrosive materials which attack the steel components in the system and form iron sulfides. The corrosion products foul the exchangers, absorbers and other parts of the system.

To reduce the corrosion that was resulting in the fouled exchangers, an oil soluble high molecular weight semi-polar compound (Inhibitor C) was added to the adsorption oil at a rate sufficient to maintain 50 ppm in the oil stream. Ammonia is added to the system to maintain the pH at from 7.5-8.0.

Fouling of the exchangers has decreased so that cleaning has not been necessary during the twelve months that the inhibitor has been used. Exchanger pressure drop indications and heat exchange coefficient values indicate that corrosion and the attendant fouling of the equipment has ceased.

The use of the inhibitor at a cost of $1.50 a day has effected at least a six fold reduction in cleaning

costs and offstream time. There also has been a significant increase in the efficiency of the heat exchangers. Although the unit has not been inspected it is reasonable to expect a very marked decrease in the corrosion on various components in the system.

Conclusion

Results of the two year program of using high molecular weight organic corrosion inhibitors lead to the following conclusions:

1. A reduction in corrosion has been found whenever an inhibitor has been used in a system and in some cases the life extension has been considerable.
2. The reduced amount of corrosion products, together with the detergent action of the inhibitor has resulted in significant reductions in maintenance and cleaning costs.
3. Some neutralization of the inhibited streams may be required to obtain the most economical results.
4. Corrosion rates based on the iron analysis of a stream may lead to erroneous corrosion rates. However, iron analysis may be used to indicate optimum inhibitor use.
5. Properly exposed corrosion test coupons generally provide the most satisfactory method of determining corrosion rates.
6. The water soluble corrosion inhibitors tested are sufficiently soluble in hydrocarbons to provide corrosion protection.
7. Carbon dioxide corrosion of steam reboilers can be controlled with these inhibitors.
8. No adverse effects on product specifications have been noted.
9. The cost of the inhibitor has been from 0.3 to 1.5 mils per barrel of unit charge.

Acknowledgment

The author expresses his appreciation to the personnel of the several refineries of the Socony-Vacuum Oil Company, Incorporated who supplied information that helped materially in the preparation of the paper.

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DISCUSSION

Question by William W. Wheeler, Pasadena, Texas: Please describe the construction and operation of the inhibitor injector shown as made of standard pipe fittings.

Reply by H. Howard Bennett:

A schematic diagram of the inhibitor injector is shown in the attached sketch and in Figure 7. The device is made of a 3-inch piece of pipe with the welded plate containing an orifice and equalizing tube. Reducing couplings provide the ends for the vessel.

Figure 1—Inhibitor injector.

The inhibitor is added to the depressured vessel through the top funnel after which the two top valves are closed. The bottom valve is then opened bringing the pressure in the vessel to that of the line. The inhibitor then slowly drips into the steam to the reboiler.

Question by William Lloyd Vorhies, Freeport Sulphur Company, Port Sulphur, La.:

Is it possible to use high molecular weight inhibi-

tors for control of corrosion in a system heating sea water to 325 F, 200 psig?

Reply by H. Howard Bennett:

Our experience has been that without deaeration little protection could be expected from the organic inhibitors in sea water. With completely de-aerated water we believe a reasonable degree of protection could be obtained if sufficient inhibitor was added.

Question by Francis J. Baird, Derby Oil Company, Wichita, Kans.:

Can results equal or comparable to those experienced with Admiralty and Monel tubes be expected with carbon steel tubes?

Reply by H. Howard Bennett:

In our work steel condenser tubes were not tested. However, at the location where the steel test coupons were exposed a reduction in corrosion of approximately 87 percent was found when 9 ppm of a water soluble type organic inhibitor was used.

Questions by Frank C. Bunker, Pan American Refining Corp., Texas City, Texas:

1. What is your experience with the injection of filming amines in ammoniacal solution?
2. On what basis is decision made to use hydrocarbon or water soluble inhibitor?
3. Do you have any difficulty with emulsion formation or excessive H_2O pickup by hydrocarbons in systems utilizing filming amines?

Replies by H. Howard Bennett:

1. We have mixed a water soluble organic inhibitor with aqueous ammonia and injected them together for over two years with good results.

2. The final choice of an inhibitor should be made on the basis of the most economical corrosion control. Available methods of introducing the inhibitor into the system and the pH range at which it must work should be considered.

3. No evidence of excessive moisture pick-up or emulsion trouble has been noted in our work with the organic film forming inhibitors.

Questions by Kenneth Roger Barker, Ashland Oil & Refining Co., Ashland, Ky.:

1. How was the amount of inhibitor in the gasoline and water determined?
2. Were any adverse effects noted when using a non-volatile inhibitor in the steam generator?
3. Was the condensate piping protected by the inhibitor added to the steam?

Replies by H. Howard Bennett:

1. The amount of the water soluble organic inhibitor in the water layer was determined by a colorimetric method developed by the manufacturer of the inhibitor. The amount in the gasoline layer was determined by difference.

2. We have not used a non-volatile inhibitor in a steam generator. We have noticed no adverse effects from its use in a steam heated reboiler.

3. The results to date indicate that the inhibitor protects the condensate piping as well as the reboiler.

A New Method for Measuring Potentials Of Polarized Electrodes in Soil Corrosion Cells*

By W. NEIGHBOURS*

Summary

A method of interrupting the current through a soil corrosion cell and of measuring the potentials of the polarized electrodes during the period of interruption is described. An electronic circuit is used to interrupt the current and the potential across the cell at interruption is balanced against a known potential, an oscilloscope being used as a null indicator.

Introduction

FOR SOIL CORROSION investigations being carried out at the Soil Bureau of the New Zealand Department of Scientific and Industrial Research, a method designed by Hickling[1] and applied by Denison and Darnielle[2,3] was tried, but it was felt that some improvements could be made in the technique of measurement by using a visual method with oscilloscope presentation rather than the aural method of the Hickling meter. A circuit was accordingly developed along these lines and has proved to be satisfactory in the measurement of potentials of soil corrosion cells.

General Description of Method

The new method is shown in the block diagram, Figure 1. A is a sharp trigger pulse generator using a free running multivibrator circuit. The output from the master trigger is connected to the pulse shaping multivibrator B which operates only when a trigger is received from A. The output from B, which consists of a negative pulse of the desired interruption period and about 200 volts in amplitude, is used to control the rest of the apparatus consisting of the switching tube F, the time base generator C, and the time marking oscillator E. The negative pulse from B is applied to the switch tube F and this effects a complete interruption of the current from the power supply K to the corrosion cell G. The amplitude of the current through the cell is controlled by adjusting the grid bias of the switching tube and the negative voltage pulse causing interruption is superimposed on this average bias. The sweep time base C deflects the oscilloscope beam from left to right at a constant rate during the interruption period, thus providing the horizontal component in the visual presentation. The time marking oscillator E is quiescent while current is flowing through the soil cell, but oscillates during the period of interruption, i.e., while the negative impulse from B is received. The output from this oscillator is applied to the grid of the cathode ray tube resulting in changes of intensity of the beam at the frequency of the oscillator and thus providing marks as the beam is being deflected and enabling the time of interruption to be quickly and accurately determined.

The potential, during the period of interruption, across the cell and the potentiometer (connected in series) is amplified by the DC amplifier H and applied to the Y or vertical deflecting plates of the cathode ray tube.

When a measurement is being taken the switch S, as shown in Figure 1, is used to change from the cell and potentiometer in series to a resistance of approximately the same value as that of the cell. The vertical height of the horizontal trace on the screen is an indication of the potential between the point R and earth during interruption of the current. When the current is passed through the resistance there is no polarization and so the potential at interruption is zero, but when the current is applied to the cell and potentiometer in series the resultant potential at interruption is the potential of the cell and that across PQ. If P is varied so that the position of the trace on the oscilloscope is the same whether the resistance or the cell and potentiometer are in the circuit then the potential across PQ (which is known) must be equal and opposite to the polarization potential of the soil cell. Thus the oscilloscope is used as a null indicator, and the potential at interruption is read off directly in terms of the back voltage introduced by the calibrated potentiometer.

Detailed Description of Circuit

The circuit is shown in detail in Figure 2. V_1 is a double triode arranged as a free running multivibrator which, due to the blocking effect of the high impedance cathode circuit in the second section and the direct coupling between the plate of the first section and the grid of the second, produces a short trigger pulse which is used to trigger V_2. V_2 is a

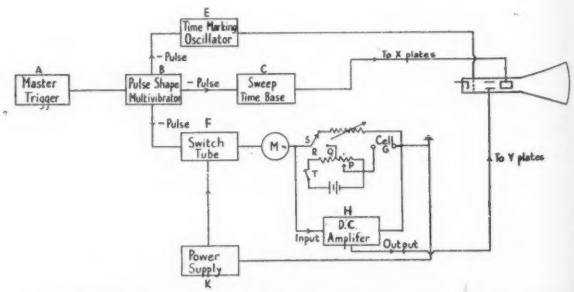

Figure 1 — Block diagram showing new method for Denison cell test.

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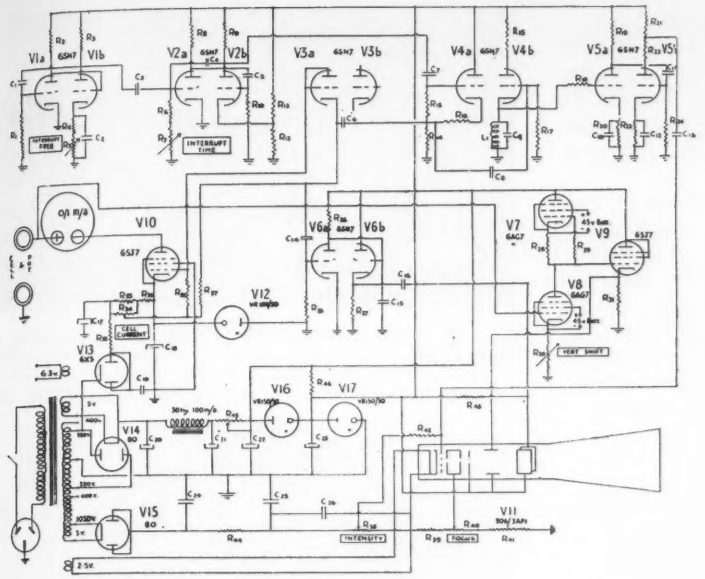
*Late of the Radio Development Laboratory, Dept. of Scientific and Industrial Research, Wellington, N.Z.



Resisters

$R_1, R_{14}, R_{16}, R_{17}, R_{19}, R_{21}$	250,000 ohms, 1w	R_{22}	10,000 ohms, 3w
R_2	100,000 ohms, 1w	R_{23}	500 ohms, 1w
R_3, R_{13}, R_{18}	10,000 ohms, 1w	R_{24}	2 megohms, 1w
R_4	3 megohms, 1w	R_{25}	1 megohm, 1w
R_5, R_9, R_{20}, R_{27}	50,000 ohms, 1w	R_{26}	5000 ohms, 25w voltage divider tapped at 300V
R_6, R_8, R_{11}, R_{12}	25,000 ohms, 1w	**Potentiometers**	
$R_{28}, R_{29}, R_{30}, R_{31}, R_{32}, R_{34}$	500,000 ohms, 1w	R_7	2 megohms.
$R_{33}, R_{35}, R_{36}, R_{37}, R_{38}$	2,000 ohms, 1w	R_{10}, R_{40}	500,000 ohms.
R_{39}	5,000 ohms, 1w	R_{42}	100 ohms.
R_{41}, R_{43}	15000 ohms, 1w	R_{34}	5000 ohms.
R_{44}	100 ohms, 1w	R_{45}	100,000 ohms.

Condensers

C_1, C_2	0·01 mfd. 600v	C_{19}	1mfd. 600v
C_3	100 pfd. 500v	C_{20}	10mfd. 500v
C_4	500 pfd. 500v	C_{21}	8 mfd. 450v
$C_5, C_{16}, C_{17}, C_{18}$	0·05 mfd. 600v	C_{23}	8mfd. 250v
C_6, C_7, C_8, C_{24}	0·1 mfd. 600v	C_{24}, C_{25}	1mfd., 2kv
C_9, L_1	Resonant at 10000 c/s	C_{26}	0·75 mfd. 400v
C_{11}	50 pfd., 500v		
C_{12}	0·01 mfd., 2 kv.		
C_{13}	0·004 mfd., 500v		
C_{14}, C_{22}	16 mfd. 450v		
C_{15}	8 mfd., 450v		

Figure 2 — New circuit for Denison cell test.

multivibrator with the second section biassed beyond cut-off so that this stage is normally quiescent. The cathode of the second section of V_2 is taken to a tap on a potential divider between B+ and earth and the grid leak is taken to ground giving a negative bias to this section of approximately 25 volts, sufficient to cut off this side completely. The first section of V_2 is normally conducting as both cathode and grid resistor are returned to ground. Thus there is a low voltage on the plate of V_2a due to the drop across the plate resistor, and the anode of V_2b is at full HT because this side is cut off. The short negative trigger coming from V_1 is applied to the grid of V_2a and is of sufficient amplitude to cut this section off completely. The plate voltage now rises on V_2a and this rising wave-front is applied to the grid of V_2b via the resistance capacity coupling. Thus the grid of V_2b rises above the cut-off point and V_2b commences to conduct. The plate voltage on V_2b starts to fall because of the IR drop in the plate resistor and this falling wave-front is communicated back to the grid of V_2a. In this way a cumulative action is started and the sections of V_2 rapidly reverse roles, V_2a being cut-off and V_2b being in a conducting state. The negative charge on the grid of V_2a then leaks away through the grid resistor, and after a period, depending on the time constant of the grid resistor and the coupling condenser to the plate of V_2b, V_2a again commences to conduct. The above action is now reversed and the stage then reverts to its normal quiescent state to await the next pulse from V_1 which is much shorter than the smallest desired time of cell current interruption. Therefore, at the moment of the trigger there is a positive going pulse on the plate of V_2a and a negative going pulse on the plate of V_2b, both of which are of the same duration. This pulse time, which is the time of interruption of the cell current, is controlled by means of the variable resistor in the grid circuit of V_2a from about 10^{-4} to 10^{-3} seconds. The frequency of interruption, or the frequency of triggering by V_1 is controlled by the variable resistor in the cathode circuit of V_1b.

The negative going pulse on V_2b is then fed to the first section of V_4 which is arranged as a cathode follower buffer stage, and from the cathode of this stage the negative pulse of about 100 volts is used to control the rest of the circuit.

V_{10} is a pentode which controls the current through the soil cell. 150 volts negative is fed to the cathode of this tube and the plate goes to ground through the milliameter and the soil cell in series. The standing current is controlled by varying the grid bias on V_{10} by means of the potentiometer R_{34}. This current is completely interrupted by the negative pulse from V_4a through the diode V_3a. The purpose of this diode is to eliminate the positive kick-back which would otherwise appear after the negative pulse on the grid of V_{10}, due to the coupling condenser. The interruption pulse by this method approximates the ideal rectangular form, so effecting complete cut-off for the pre-determined time.

At the same time that the current is interrupted in V_{10}, V_6a is also cut off and the condenser C_{15} charges up towards B+. This rising voltage, after passing through the cathode-follower section V_6b is applied to the x plates of the oscilloscope and causes the beam to move from left to right. The distance that the beam traverses depends on the time of the master negative pulse, i.e., the horizontal sweep occurs during the period of interruption.

Section b of V_4 normally has its grid at earth potential and is therefore conducting. The plate current of this tube passes through an LC circuit tuned to 10,000 cycles per second. The master negative pulse cuts this stage off also, and the current in the tuned circuit dies away as a train of damped oscillations at its resonant frequency. This train of oscillations lasts for the duration of the negative pulse, i.e., during the interruption period, and after amplification and limiting at V_5a and b where all the oscil-

lations are brought to the same level the train is applied to the grid of the cathode ray tube, and as the sweep moves from left to right a series of timing marks (one for each 10^{-4} sec.) are described which serve to calibrate the duration of the negative pulse and consequently the time of interruption of the cell current.

V_7, V_8 and V_9 constitute a DC amplifier and cathode-follower output stage which is connected to the Y plates of the cathode ray tube, and the input of which is across the soil cell and external potentiometer. Therefore the potential across the cell and potentiometer during interruption governs the height of the sweep of the scope beam while the duration of interruption controls the length of sweep in the horizontal direction.

Constructional Details

The circuit as shown in Figure 2 was enclosed in a case 44 cm. long, 25 cm. wide and 30 cm. high, which is shown together with the rest of the apparatus used in the test in Figure 3. The soil cell is normally enclosed in a sealed glass jar even while under test, in order to minimize moisture loss, but the jar is omitted in Figure 3 for the sake of clearness. The cell is made of transparent acrylic plastic in three pieces and is the same in principle as that described by Denison and Darnielle[2]. The construction of the potentiometer used to balance the potential across the cell is shown in Figure 4. It consists of a machined frame, the sliding part of which contains a bakelite drum on which is wound ten turns of resistance wire. This part is arranged to slide on two supports in the fixed part of the frame, one of which can be seen on the right in the photograph. A screw thread on the dial shaft engages in a threaded hole in the center of the sliding drum. This thread is arranged to have the same pitch as the resistance winding. An extension on the threaded shaft at the rear of the potentiometer carries the wiping arm shown in the photograph. Thus as the wiping arm revolves the drum slides in or out according to the direction of rotation keeping the consecutive turns of the coil under the arm. The wiping contact is an inclined copper roller. An engraved indicating rod which projects through the front of the case shows which turn of the coil is under the arm.

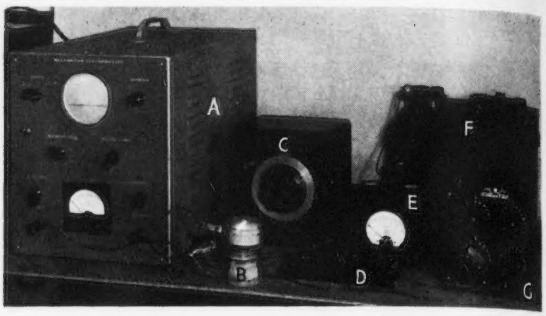


Figure 3 — Apparatus for Denison cell test. A — Circuit shown diagrammatically in Figure 2. B—Soil cell. C—Potentiometer. D—Switches (2) shown as S and T in Figure 1. E — Voltmeter across battery F. F—Battery across potentiometer C. G—Resistance box (0-10,000 ohms).

Figure 4 — Potentiometer used in Denison cell test.

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Corrosion and Erosion-Corrosion Of Some Metals and Alloys By Strong Nitric Acid*

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Abstract

The corrosion and erosion-corrosion resistance of several stainless steels and aluminum alloys in strong nitric acid in the temperature range of room temperature to 160 F were investigated. In general the stainless steels show a marked increase in corrosion with increasing temperature. Galvanic couple systems of aluminum and stainless steel show the stainless steel to be protected by the aluminum which acts as a sacrificial anode in strong nitric acid. Polarization studies on aluminum and stainless steel provide some interesting information concerning the corrosion behavior of the aluminum-stainless steel couple system.

Erosion-corrosion tests show that the rate of attack on stainless steel decreases with increasing velocity of acid flow; the rate of attack on aluminum tends to increase with increasing velocity of acid flow. Experiments were conducted on both rotating specimens and on stationary specimens in a system involving a flowing solution.

A detailed description of the equipment used for the polarization and the erosion-corrosion studies is included.

Introduction

FOREMOST among the metals with suitable corrosion resistance to fuming nitric acid and strength properties are the aluminum alloys, titanium and some of the stainless steels.[1,2,3,4,5] It often is necessary to have more than one of these materials in the same piece of apparatus and thus galvanic or bimetallic corrosion is encountered. The galvanic couple formed by aluminum and stainless steel in fuming nitric acid is a frequently encountered example and was selected for study in this investigation. This couple possesses a peculiarity in that the aluminum, normally the more corrosion resistant of the two materials, forms the anode of the couple and suffers heavy attack. The stainless steel, normally heavily attacked by the acid at temperatures in the 110-160 F range, becomes the cathode of the couple and is almost completely corrosion free. This phenomenon holds for tests conducted in acid under static and flowing conditions. The majority of these tests were concerned with 2S aluminum, 3S aluminum and Type 347 stainless steel.

Polarization studies were conducted on the above materials in order to explain the results of the couple tests. This was accomplished by examining the effect of current density on polarization and relating these results with corrosion films and reaction products occurring on the electrodes studied.

Erosion-Corrosion experiments showed that solution velocity has an effect on corrosion and that these results may be explained on the basis of information obtained from the polarization experiments.

Procedure and Apparatus

Galvanic Corrosion Couples

Specimens of aluminum and stainless steel measuring 1 by 1 by 0.06-inch were drilled to produce a 0.25-inch hole at the centers and prepared as described in the section on corrosion testing. These specimens were then assembled to form a galvanic cell as indicated in Figure 1. This design permits complete immersion of the cell into the acid and maintains a constant distance between electrodes which was set at 1 inch for this investigation. Screws made of the same material as the specimens being tested serve as electrical contacts between the electrodes. The Teflon tube insulates the steel contact spring and the threaded portion of the screws from the acid. Corrosion rates are calculated for the exposed portions of the specimens only and are based on five 48-hour test periods.

Galvanic couple tests in the erosion-corrosion tester were made on the orifice specimens, see (12), Figure 2. For these tests specimens of different materials are placed in each of the orifice assemblies at a fixed

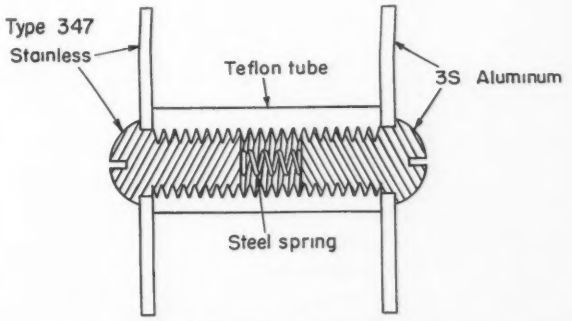

Figure 1—Galvanic Corrosion couple.

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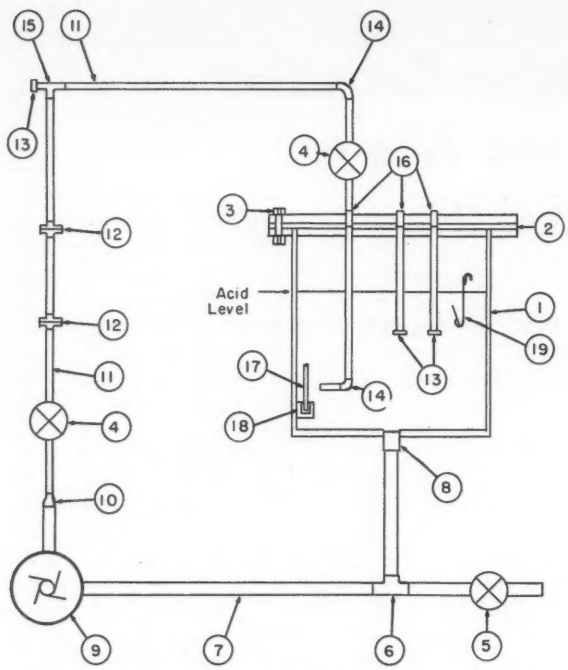

Figure 2—Schematic illustration of erosion-corrosion apparatus.

1. Aluminum tank, 17.5 x 16 D, 2S-H14, top and bottom ½-inch plate, cylinder 3/16-inch sheet.
2. Kel-F gasket.
3. Machine bolt, ½-inch.
4. Durimet-20 valve, flanged fittings of B-214 aluminum, ½-inch.
5. Durimet-20 valve, flanged fittings of B-214 aluminum, 1 inch.
6. Tee, B-214 aluminum fittings, 1 inch.
7. Pipe system, 61S-T6 aluminum pipe, 1 inch.
8. Coupling, B-214 aluminum fitting, 1 inch.
9. Durimet-20, Model 30, Series W4A, centrifugal Durcopump; flanged fittings, B-214 aluminum, 1 inch.
10. Reducer, B-214 aluminum, 1 x ½-inch.
11. Pipe system, 3S-H18 aluminum pipe, ½-inch.
12. Orifice test specimen (see Figure 7).
13. Plug, B-214 aluminum, ½-inch.
14. Elbow 90°, B-214 aluminum, ½-inch.
15. Tee, B-214 aluminum, ½-inch.
16. Coupling, B-214 aluminum, ½-inch.
17. Impingement specimen, 5 x 5 inches.
18. Impingement specimen holder, 2S-H14 sheet aluminum, fitted with Teflon wedge.
19. Turbulence specimen, 1 x 1-inch, suspended in glass cradle.

distance apart. The electrical circuit is completed through an aluminum wire connected externally to the orifice specimens.

Polarization Apparatus

The equipment used in the polarization studies is illustrated in Figure 3 and was designed after that of Mears and Brown.[6] Since the saturated calomel reference electrode could not be inserted directly in the fuming nitric acid a salt bridge modification of the Mears and Brown apparatus was devised and is illustrated schematically in Figure 4. The method for attaching the aluminum and stainless steel specimens is shown in Figure 5. These specimens are machined cylinders 0.5-inch in diameter by 0.5-inch long with a small hole tapped in one end to receive the stainless steel rod for making the necessary electrical connections. The stainless steel rod is isolated from the acid by the use of Teflon gaskets and a length of pyrex tubing.

The polarization of an aluminum anode by impressed current is determined by using only electrodes A and C of Figure 3. A battery is connected to cause anodic polarization of the aluminum specimen. Switches S_1 and S_2 are closed and the impressed current is controlled by means of the variable resistance R. The potential difference between the saturated calomel electrode and the aluminum anode is measured with a potentiometer at each value of impressed current by closing switch S_3 to the B position. Cathodic polarization of a stainless steel electrode is determined in a similar manner except that electrodes A and B are used. Switches S_1 and S_2 are closed and S_3 is closed to position A. Thus the polarization of each electrode is determined separately and polarization curves of the Evans type are drawn. By closing only switches S_1 and S_4 the natural couple of aluminum and stainless steel may be studied.

Potential values given for aluminum and stainless steel in this paper are not true equilibrium values but approach that of a steady state value. The reason

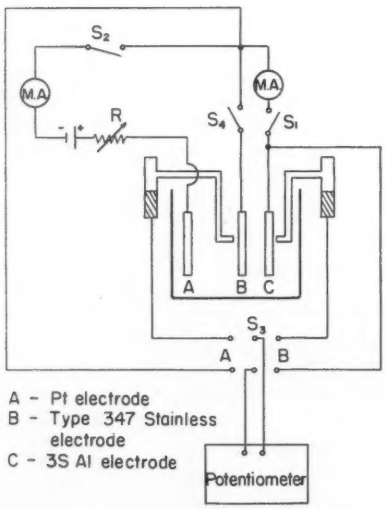

Figure 3—Schematic illustration of apparatus for measuring electrode potentials.

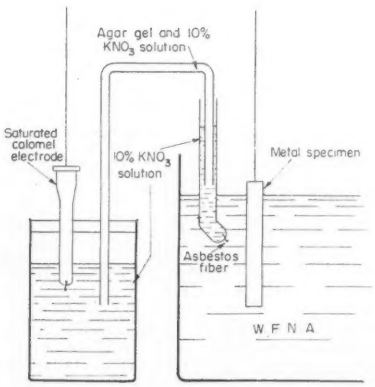

Figure 4—Detail of salt bridge construction.

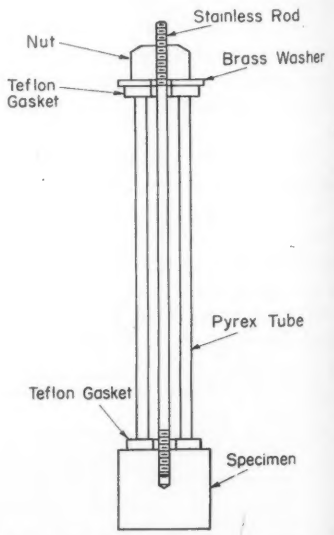

Figure 5—Polarization test specimen holder.

for this is that at the temperature at which the tests were conducted the decomposition of the fuming acid was sufficient to cause changes in the acid composition and reaction products due to corrosion altered the test solution. Therefore, it would be difficult to obtain steady state values in a constantly changing environment. Numerous tests made on aluminum and stainless steel showed that the stainless steel reached a fairly steady potential within a short time after the current was applied. The aluminum, however, showed a rapid change in potential during the first few minutes of testing after which the potential changed slowly with time. Values reported are those obtained after a time when the change of potential with time was small. Such values were felt to be valid because of the nature of the acid and because most of the corrosion tests were conducted over a relatively short time.

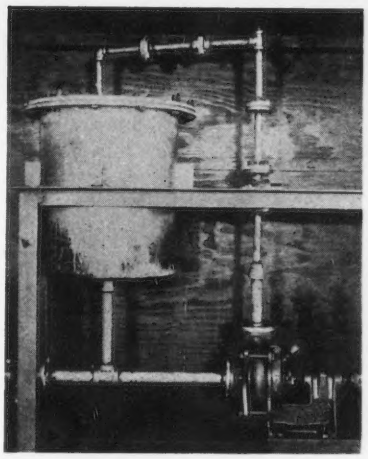

Figure 6—Erosion-corrosion apparatus.

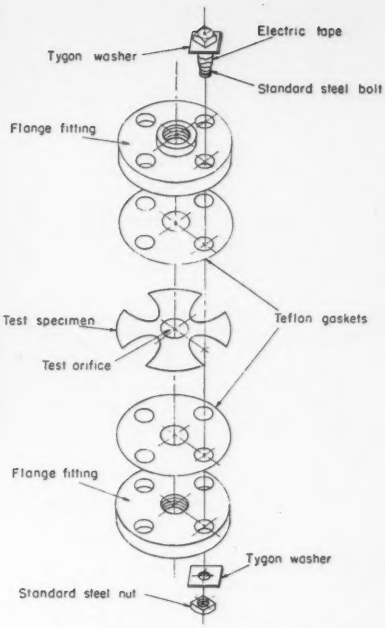

Figure 7—Exploded view of orifice test specimen assembly for erosion-corrosion tester.

Erosion-Corrosion Apparatus

A schematic illustration and photograph of the erosion-corrosion apparatus are shown in Figures 2 and 6 respectively. The tank (1) has a capacity of 17.4 gallons and is two-thirds full when in operation. The test solution, white fuming nitric acid, passes through the system at a velocity controlled by the orifice size. Reynolds numbers determined for flow in the pipe system and through the orifices were 86,500 or higher, showing that turbulent flow conditions were present.

The orifice test specimen (12) is insulated from the system proper as illustrated in Figure 7. In this assembly the Teflon gaskets serve to insulate the test specimen while the electrical tape and Tygon washers insulate the system on one side of the orifice specimen from that on the other side. The Durimet 20 valves (4, 5) and pump (9) are insulated from the aluminum system in a similar manner to guard against galvanic corrosion. Insulation of the impingement specimen (17) is accomplished by means of a piece of Teflon sheet utilized as a wedge between the specimen and specimen holder (18). Turbulence specimens (19) are suspended in the solution by glass cradles which are hooked over an aluminum wire positioned across the tank and several inches above the solution level.

When the erosion-corrosion apparatus is in operation the acid is passed through the pipe system by means of the centrifugal pump (9). The solution is impelled through the test orifice (12) and finally is directed upon the impingement specimen (17).

TABLE 1
Nominal Compositions of Metals and Alloys Used in Corrosion Studies

MATERIAL	PERCENTAGE OF ELEMENT															
	Al	Mg	Si	Cu	Zr	Mo	Cr	Ni	C	Mn	P	S	Fe	Cb	Co	W
Aluminum, Wrought:																
2S	bal															
61S	bal	1.0	0.6	0.25			0.25									
3S	bal									1.2						
14S	bal	0.4	0.8	4.4						0.8						
24S	bal	1.5		4.5						0.6						
52S	bal	2.5					0.25									
75S	bal	2.5		1.5	5.5		0.3			0.2						
63S	bal	0.7	0.4													
4S	bal	1.0								1.2						
Aluminum, Cast:																
B-214	bal	3.8	1.8													
Stainless Steel and Others:																
AISI 304			1.0				18.	8–11	0.08	2.0	0.04	0.03	bal			
AISI 304 ELC			1.0				18.	8–11	0.02	2.0	0.04	0.03	bal			
AISI 347			1.0				17–19	9–12	0.08	2.0	0.04	0.03	bal	0.8		
AISI 430			1.0				14–18		0.12	1.0	0.04	0.03	bal			
Durimet 20			1.15	3.84		2.62	20	29.7	0.05	0.39			bal			
Haynes 25 (L-605)			0.5				20	10	0.1	1.5				2	50	15
Titanium	Commercial grade containing <0.2 carbon															

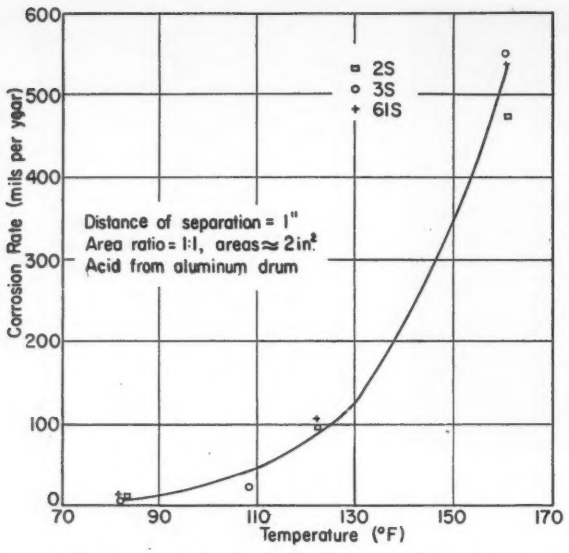

Figure 8—Corrosion of aluminum coupled to Type 347 stainless steel in white fuming nitric acid.

TABLE 2

Corrosion and Erosion-Corrosion Rates of Galvanic Couples of Aluminum and Stainless Steel by Fuming Nitric Acid at 108 F.
(Acid velocity constant at 6.2 ft./sec. for orifice test)

Test Condition	RATE IN MPY	
	Type 347	3S Aluminum
Static Test[1]	1	12
Turbulence Test	1	15
Orifice Test[2]	1	16

[1] Rates for static and tubulence tests are averages of five 48-hour periods.
[2] Rates are averages of four 24-hour periods.

Loading of the system is accomplished by removing the lid which is gasketed at the top of the tank by a Kel-F ring. The acid is removed by opening a valve (5) at the lowest part of the system. Tests were conducted for 21-day periods at a temperature of 108 F which was the normal operating temperature of the apparatus. Control specimens of aluminum were placed in the tank every two days for the entire three weeks' duration. Corrosion rates on these specimens were constant and therefore indicated that changes in acid composition over the three-week period had little influence on the test results.

Erosion-corrosion tests also were conducted on rotating specimens in an acid bath. For this test the specimen is fastened to a Teflon shaft by means of a bolt constructed of the same material as the specimen. An air stirrer or electric motor is used to rotate the Teflon rod and specimen in the acid bath. Speeds of rotation were determined with the aid of a stroboscope.

Specimen Preparation and Corrosion Testing

Corrosion specimens were prepared from sheet and round stock depending on the type of test to be made. In general the specimen sizes were approximately 1 by 1 by 0.06-inch for the ordinary weight loss and galvanic couple tests. Orifice and impingement specimens used in the erosion-corrosion unit were made from the same sheet material but were of a larger size as described in the section on apparatus. Specimens used in the polarization studies were made from round stock because of the equipment design and requirements. Except for the polarization specimens and parts of the erosion-corrosion apparatus used as test pieces, the specimens were in all cases polished on grit No. 120 emery cloth and degreased in acetone prior to testing. Polarization specimens were polished on grit No. 400 emery cloth and degreased in ethyl alcohol before testing. The various parts of the erosion-corrosion apparatus used as corrosion specimens were degreased in acetone before being assembled but received no other surface preparation.

Where possible, a solution volume of at least 150 ml per square inch of specimen area was used. The test solution was changed every 48 hours except where indicated. Weight loss tests and galvanic couple tests were conducted in wide mouth Erlenmyer flasks of 1000 ml capacity equipped with finger type condensers. Corrosion rates are based on weight loss and are calculated in mils penetration per year.

Nominal compositions of materials used in the testing program are given in Table 1. All tests reported were made in white fuming nitric acid obtained from the General Chemical Division of the Allied Chemical and Dye Corporation and shipped in 55-gallon aluminum drums. The analysis of the acid is approximately 98.8% HNO_3, 1.2% H_2O and 0.2% NO_2. The composition varied some from lot to lot and with storage time because of acid decomposition, but these variables were negligible in comparison to changes which took place during corrosion testing, especially at the higher temperatures.

Results and Discussion

Galvanic Couples

Tests were made of Type 347 stainless steel-2S aluminum couples in white fuming nitric acid. The results are striking in that they show almost complete protection of stainless steel (corrosion rates of 1 mil per year or less) by the aluminum over the entire temperature range from ambient to 160 F. Uncoupled or control specimens of Type 347 stainless steel are very resistant to fuming nitric acid at room temperature (about 75 F) and corrode at a rate of 1 mil per year or less but as the temperature is increased the corrosion resistance of the alloy is lost and appreciable rates in the order of 100 mils per year are encountered at slightly over 100 F. The attack becomes more severe as the temperature is increased to 160 F resulting in corrosion rates in excess of 200 mils per year. The 2S aluminum control specimens show low corrosion rates at all temperatures up to 160 F, which was the highest temperature used in this investigation. Corrosion rates in the 5-10 mil per year range were observed for the 160 F tests. Some typical results illustrating the effect of temperature on the corrosion of 2S, 3S and 61S aluminum when coupled to Type 347 stainless steel are plotted in Figure 8. There was little effect of velocity of acid flow on the galvanic couple as

shown by tests conducted in the erosion-corrosion unit and reported in Table 2. These tests were run at 108 F and show only a slight increase in the corrosion of the aluminum anode in going from the static (control) test to the orifice test.

The effectiveness of the couple under both conditions of testing suggests the possibility of cathodic protection for stainless steel equipment handling fuming nitric acid. However, contamination of the acid with aluminum nitrate resulting from the severe corrosion on coupled aluminum, especially at the higher temperatures, presents a serious problem. The contamination difficulty might be overcome by the utilization of impressed currents in place of the sacrificial aluminum anode. This aspect is presently being studied from the standpoint of minimum current requirements and resulting acid decomposition.

Polarization of 2S Aluminum and Type 347 Stainless Steel

In view of the practical applications which could be derived from the galvanic couple tests, it was felt that valuable information could be obtained by studying the polarization characteristics of aluminum and stainless steel in fuming nitric acid. The polarization apparatus described above was devised for this investigation. Although considerable work is being done at the present time at temperatures below 160 F, the discussion in this article will be concerned only with the tests at 160 F.

The electrode potential of aluminum in white fuming nitric acid was found to be positive to the saturated calomel electrode and junction arrangement used at all current densities tested. This agrees with the findings of Steiner and Kahlenberg[7] who state however that the potential becomes negative at dilutions greater than 56 percent. The potential was found to become more positive with increased current density. Figure 9 shows that the polarization curve is not a smooth function but consists of three separate regions. Region A occurs at the higher values of applied current and is characterized by a thick coating which forms on the specimen. Region B is a range of periodic fluctuations of electrode potentials and impressed currents and region C occurs at low current densities and is characterized by an oxide film on the specimen. The periodic effect demonstrated in region B has been observed previously by Hedges[8] who attributes the periodicity to equal thermodynamic probabilities of the specimen to remain in either the coated or the film free state.

X-ray and electron diffraction analyses of the films formed on aluminum anodes showed characteristic patterns of amorphous or microcrystalline aluminum oxide. These studies were made only after the coated specimens of aluminum had been exposed to air for several hours. The nitrate films formed on aluminum in fuming nitric acid are loosely adhering and appreciable quantities of precipitate form in the test solutions after long exposure times. This precipitate was identified as Al $(NO_3)_3$. Attempts to measure the water of hydration yielded anomalous results, but Seligman and Williams[9] state that in nitric acids of

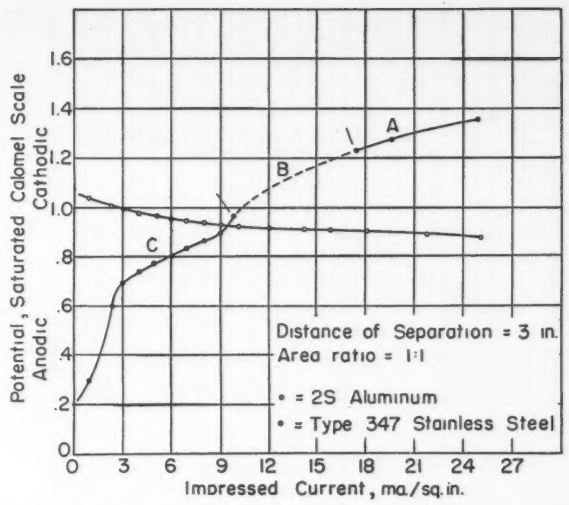

Figure 9—Polarization of 2S aluminum and Type 347 stainless steel in white fuming nitric acid at 160 F.

more than 81 percent concentration only the hexahydrate is stable.

The aluminum polarization curve could be produced only by starting each test at a high current density and subsequently reducing the current to a lower value. If one attempted to start at low current densities and subsequently increase the current after a time at low current density, the potential shifted suddenly to a very cathodic value and the impressed current decreased to a low value above which it could not be increased, probably because a protective oxide is formed at the lower current densities.

From these experimental facts, an explanation of the mechanism of polarization can be developed. In the fuming nitric acid two agents are present which can accept the Al^{+++} ion as it is produced at the anode. One is nascent oxygen which is produced through thermal decomposition of the acid. The other is the NO_3-ion. At high current densities the reaction will primarily be with the NO_3-ion, the supply of which will vary directly with the impressed current. The supply of oxygen atoms to the anode is not current dependent and therefore will be essentially constant at all current values. Therefore the polarizing film in region A will consist largely of $Al(NO_3)_3 \cdot 6H_2O$ and a lesser amount of Al_2O_3, probably also hydrated. At low current densities the amount of oxide film will be about the same, but there will be less nitrate film. Therefore, region C can be regarded as oxide film polarization and region A as oxide film polarization plus nitrate film polarization. Region B is the transition range from one type of polarization to the other.

Water added to fuming nitric acid may be expected to perform two functions. It supplies the necessary water of hydration for precipitation of aluminum nitrate and it increases the solubility limit of the acid for the Al^{+++} ion. Therefore, it will provide for increased precipitation of nitrate until present in large excess when it will cause rapid solution of precipitated nitrate. Since $Al(NO_3)_3 \cdot 6H_2O$ is

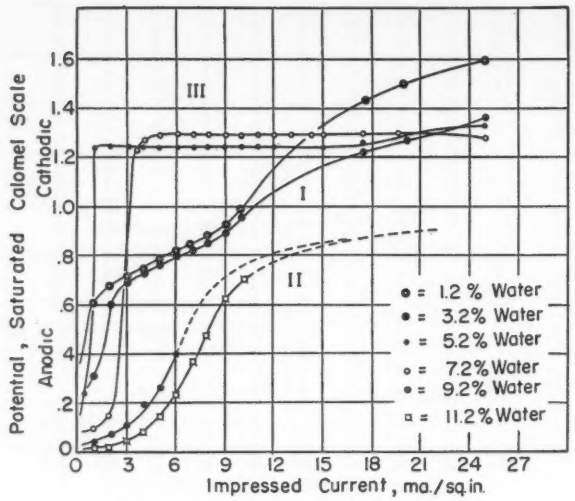

Figure 10—Polarization of 2S aluminum in aqueous solutions of white fuming nitric acid at 160 F.

Figure 11—Anode of 2S aluminum tested in 94.8 percent white fuming nitric acid at 160 F.

stable only in concentrated nitric acid the solubility of the compound could not be determined directly. However, a sample of test acid containing the precipitated nitrate was gradually diluted with no effect until about 6 percent water had been added (thus making a solution of approximately 7 percent total water content) at which point the precipitate was seen to dissolve rather suddenly. Repeated observations of this phenomenon are regarded as indirect evidence of the effect of water on the solubility of the acid for the nitrate.

Water in the test acid might then be expected to affect the polarization of an aluminum anode. Figure 10 shows that water does markedly alter the polarization of aluminum. Three types of curves were observed. At low water concentrations (1.2 and 3.2 percent water) the curves are typical of the one previously discussed, Type I. Regions A, B and C are present. The specimen appears coated and precipitate is found in the test solution. At high water contents (9.2 and 11.2 percent water) the nitrate polarization region is not present, Type II. The specimen appears bright, shiny and has no visible coating. The high water content has increased the solubility of the acid for the nitrate so that no nitrate precipitation occurs on the specimen or in the test solution. At intermediate water contents (5.2 and 7.2 percent water), polarization curves of Type III are obtained. The specimen shows large definite areas which have the coated appearance of Type I specimens and other areas with the shiny appearance which is typical of Type II specimens. Figure 11 is a photograph of such a specimen. The nitrate polarization is maintained to a fairly low current value because of a water supply which is plentiful enough to provide heavy precipitation on some surface areas without excessive re-solution.

Region B which appears in all the polarization curves can also be explained by means of the water phenomena. As the current is decreased the supply of nitrate ion to the anode decreases. In the range of periodicity, the precipitation of the hydrated nitrate causes the potential to shift in the cathodic direction and the current to decrease. The precipitation has therefore reduced the water in the solution adjacent to the anode and decreased the supply of nitrate ion. Precipitation ceases. Water then diffuses into the region, solution of the nitrate begins which releases more water and solution proceeds almost autocatalytically. The removal of anode precipitate causes a fresh surge of current and the cycle repeats. Such periodicity has been observed to continue unabated for a period of more than six hours. When the water content is high as in the Type II curves, region B is greatly extended. The region B in Type III curves is extremely limited and occurs at the apex of the curve.

Direct solution of aluminum oxide is one possible means of destruction of the oxide film. Another possibility is the reaction of the oxide film with the nitric acid according to the theoretical equation:

$$Al_2O_3 + 6HNO_3 + 9H_2O = 2Al(NO_3)_3 \cdot 6H_2O$$

The free energy change for the reaction would be:

$$\Delta F \text{ reaction} = 2\,\Delta F_f Al(NO_3)_3 \cdot 6H_2O - \Delta F_f Al_2O_3 + 9\,\Delta F_f H_2O + 6\,\Delta F_f HNO_3$$

The necessary thermodynamic data has been found for 25 C.

ΔF_f of $Al(NO_3)_3 \cdot 6H_2O$ = — 526,230 cal/mole[10]
ΔF_f H_2O = — 56,690 cal/mole[11]
ΔF_f HNO_3 = — 26,500 cal/mole[12]
ΔF_f Al_2O_3 = — 381,600 cal/mole[13]

Substituting these values in the free energy equation we obtain

$$\Delta F \text{ reaction} = -1{,}052{,}000 - 1{,}050{,}835$$
$$\Delta F \text{ reaction} = -1{,}165 \text{ cal/mole at } 25°C.$$

Thus it is thermodynamically possible that aluminum oxide may be converted to aluminum nitrate. There is also the film repair mechanism of direct chemical oxidation of the aluminum by nascent oxygen.

It is possible on the basis of the experimental evidence to explain how aluminum, normally quite resistant to fuming nitric acid, becomes readily attacked when made a member of a galvanic couple with stainless steel. A piece of aluminum in nitric acid corrodes because of the development of local anodes and cathodes on its surface. The oxide film is damaged in places either by direct solution or by conversion to

nitrate or both and produces areas which become anodes. At these local anodes two competing reactions take place. One, chemical oxidation, tends to heal the film. The other, deposition of aluminum nitrate, tends to prevent oxidation by covering the anodic spot with a layer of aluminum nitrate. Since the potential difference between anodes and cathodes is small, the nitrate ion is not supplied to the anode very rapidly. Therefore a high proportion of the total anode reaction is film repair and corrosion proceeds slowly.

Coupling the aluminum to stainless steel changes the anodic situation. As before the oxide film is damaged at certain spots by the same mechanism. Now, however, the supply of nitrate ion to the anode is plentiful because of the large potential difference between the anode and the stainless steel cathode. Therefore, most of the anode reaction is not healing oxidation but deposition of non-protective aluminum nitrate. The nitrate film might well allow outward passage of Al^{+++} ions under the pressure of potential difference and impede the inward progress of oxygen atoms. This effect would prevent healing of an anodic area and the anodic areas would spread until every part of the aluminum surface has been an anode at least temporarily. The two polarization curves in Figure 9 for aluminum and stainless steel intersect when an impressed current density of about 10 ma per sq in. is used. This value is the maximum theoretical current which can be generated by the couple and when applied in Faraday's Law gives a corrosion rate of 650 mpy as compared to the actual rate of 550 mpy indicated on the curve in Figure 8. Considering the type of measurement made, good agreement is shown between the weight loss data and the theoretical value calculated from the intersection of the polarization curves. The lower value obtained for the weight loss test can be accounted for in part by the IR drop of the couple system. Similar preliminary data at lower temperatures show good agreement.

The cathodic reaction on the stainless steel electrode is believed to be the reduction of nitric acid to nitrous acid.

Erosion-Corrosion

Erosion-corrosion data on aluminum in white fuming nitric acid at low velocities approximate those of static tests in that low rates are observed as shown in Figure 12. This curve for 3S aluminum is typical of all of the wrought aluminum alloys reported in Table 3. Specimens from the turbulence or low velocity tests (specimens suspended in tank) showed uniform films. At intermediate velocities the erosion action of the solution passing over the specimen is sufficient to remove corrosion products such as nitrates but is not strong enough to destroy the more adherent oxide film. Thus the initial anode areas remain active and preferential or pitting attack occurs. This form of corrosion is observed for those specimens tested in the velocity range of 1 to 4 feet per sec. Tests at high velocities, velocities greater than 4 feet per sec., indicate that the bulk oxide is also eroded away by the acid and as a result, uniform

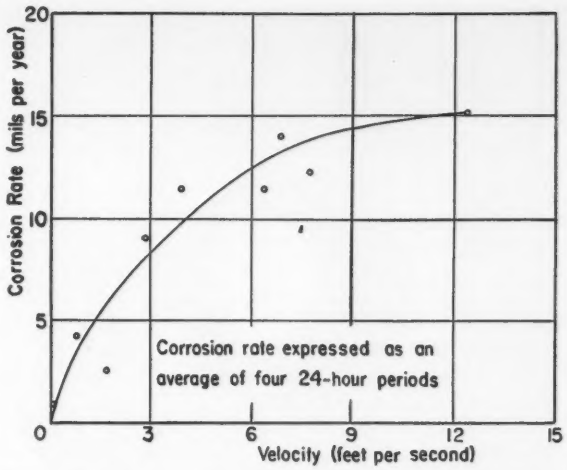

Figure 12—Erosion-corrosion of 3S aluminum by white fuming nitric acid at 108 F.

TABLE 3
Erosion-Corrosion of Some Aluminum Alloys by Fuming Nitric Acid at 108 F.
(Acid velocity constant at 6.2 ft./sec. for orifice test)

MATERIAL	EROSION-CORROSION RATE IN MPY				
	Static[1] Test	Turbulence[1] Test	Orifice[2] Test	Impingement[3] Test	Pipe[3] System
2S–H14	1	5	13	23	..
3S–H14	0.9	4	11	25	2
14S–T6	0	3	..	..	..
24S–T3	0.1	4	10	10	..
61S–T6	0.6	3	14	..	2
63S–T6	0.8	3	9	..	..
75S–T6	0.4	6	9	..	..
B-214[4]	18	56	..	..	30–100
52S–T34	0.7	3	..	..	..
4S–H14	0.4	5	..	..	..

Note: H–14 ½ strain hardened.
T–6 Solution heat treatment and artificially aged.
T–3 Solution heat treatment and cold worked.
[1] Corrosion rates averages of five 48-hour periods.
[2] Corrosion rates averages of three 24-hour periods.
[3] Corrosion rate for one 3-week period.
[4] Corrosion rate increased with each succeeding period.

erosion-corrosion showing an attack of about 15 mpy is observed. Orifice specimens display thin uniform films.

Specimens of B214 aluminum are much more susceptible to corrosion and erosion-corrosion by nitric acid than the wrought alloys. The poor resistance of the B214 cast alloy, Figure 13, may result from inclusions and/or porosity leading to concentration cell corrosion. Very severe attack was noted at a 90 degree pipe elbow at the center of the outside arc. The greater turbulence at elbows and at similar discontinuities in the direction of flow promote ideal erosion-corrosion conditions and the attack appears to be at a maximum in these areas.

The corrosion rate on aluminum is high at crevices and probably results from concentration cells set up by the relatively stagnant acid in the crevice as compared to the fresh supply of acid in adjacent areas within the system.

Results of erosion-corrosion tests on some stainless steels are given in Table 4 and correpond to the data found by Hedges[14] and Evans[15] for metals attacked autocatalytically by more dilute solutions of nitric acid. This autocatalytic attack results in the

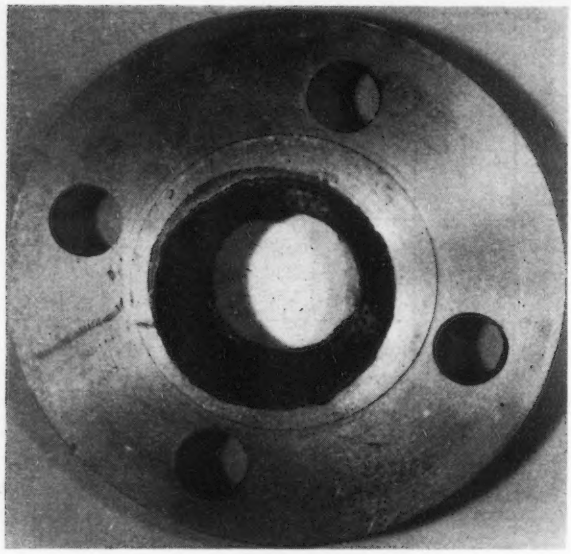

Figure 13—One-inch pipe coupling of B-214 aluminum after exposure to white fuming nitric acid in erosion-corrosion apparatus.

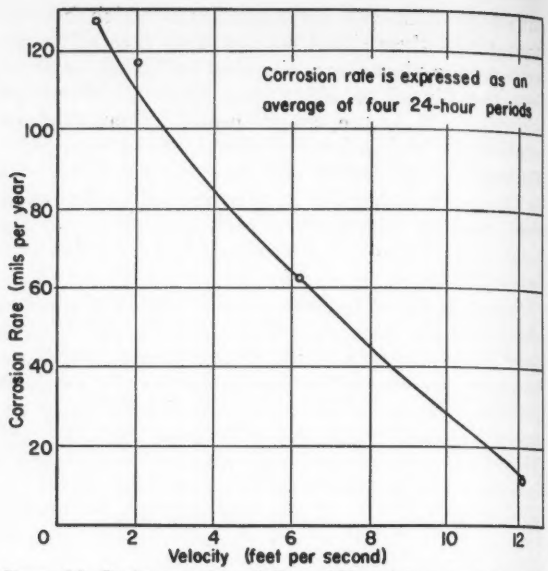

Figure 14—Erosion-corrosion of Type 347 stainless steel by white fuming nitric acid at 108 F.

TABLE 4

Erosion-Corrosion of Some Stainless Steels and Other Materials by Fuming Nitric Acid at 108 F.

(Acid velocity constant at 6.2 ft./sec. for orifice test)

MATERIAL	EROSION-CORROSION RATE IN MPY			
	Static[1] Test	Turbulence[1] Test	Orifice[2] Test	Impingement[3] Test
AISI 304	130	110	85	...
AISI 304 ELC	120	120	85	...
AISI 347	110	130	65	120
AISI 430	170	140	90	...
17-7 PH*	Pitted	Pitted	..	...
Durimet-20	20	25	20	...
Haynes-25 (L-605)	0.4	0.3	3	...
Titanium	0	0	2	...

* The analysis of this alloy was not supplied with the material. Nominal composition is 17 Cr, 7ni, 0.07 C, 1 Al, 0.6 Mn, 1 Si (max), 0.02 P, 0.03 %S. Corrosion tests were run on material heat treated as follows:
Heated 1400 F for 90 minutes and air cooled to room temperature.
Reheated to 950 F. for 30 minutes and air cooled.
[1] Corrosion rates averages of five 48-hour periods.
[2] Corrosion rates averages of three 24-hour periods.
[3] Corrosion rate for one 3-week period.

TABLE 5

Corrosion and Erosion-Corrosion Rates Of Type 347 Stainless Steel by Fuming Nitric Acid at 108 F

The peripheral velocity of the spinning specimen is approximately 1-4 ft./sec., at 480 rpm.

Test	TEST CONDITION	Rate in MPY
1	Statis Test[1]	110
2	Static Test—Oxygen bubbled through Acid	12
3	Spinning Test[2]	2

ACID SAMPLE	ANALYSES OF ACID (Percent)			
	HNO_3	NO_2	H_2O	Total Acid
Original Acid	98.73	0.18	1.08	98.97
After Test 1 Above	97.67	0.31	2.44	97.28
After Test 2 Above	93.95	0.08	5.95	94.09
After Test 3 Above	97.71	0.02	2.23	97.78

[1] Corrosion rates averages of five 48-hour periods.
[2] Erosion-corrosion rate average of four 24-hour periods.

formation of nitrous acid as the cathodic reaction; the nitrous acid then generating oxides of nitrogen. The protective film which is present on the surface of the stainless steel is apparently stable in the presence of HNO_3 but unstable in the presence of HNO_2 and the oxides of nitrogen. Thus as the velocity of the acid is increased, the corrosion reaction products of nitric acid are carried away more rapidly and the corrosion rate of the stainless steel is reduced. The erosion-corrosion rate of Type 347 stainless steel decreases in a linear manner with increasing velocity as shown in Figure 14.

A correlative test in which the specimens were rotated in a static bath of fuming nitric acid was designed to attempt to illustrate the above hypothesis more clearly. The results are shown in Table 5. The spinning specimen, in addition to carrying away the HNO_2 as it was formed at the cathodic areas, agitated the bath enough to reduce the amount of dissolved oxides of nitrogen and other reaction products of nitric acid to a negligible amount. This resulted in the lowering of the corrosion from an equivalent value of 50 mils per year at 4 feet per second in the erosion-corrosion test to a value of 2 mils per year. In a subsequent static test run with oxygen bubbled through the solution to essentially remove the lower oxides of nitrogen similar reduced corrosion rates were found. With regard to the acid compositions listed in Table 5, it may be mentioned that all nitrous acid and lower oxides of nitrogen are titrated and reported as NO_2. Figure 15 is a typical chart showing the effect of acid decomposition over a 21-day period in the erosion-corrosion tester.

Another investigation in this laboratory shows that the corrosion rates are often lower for the boiling tests than for tests conducted at lower temperatures in the same acid concentration. This reversal of corrosion rate with temperature may be explained on the basis of increasing amounts of nitrous acid and oxides of nitrogen found in the acid at temperatures slightly below boiling. Since nitrous acid and oxides

of nitrogen contribute to the corrosion process, their removal from the acid through boiling or agitation results in a reduced amount of corrosion.

Summary

Aluminum acts as a sacrificial anode when coupled to stainless steel and immersed in fuming nitric acid. The couple is effective in providing protection to the stainless steel in the temperature range investigated, ambient to 160 F. Erosion-corrosion data show that the velocity of acid flow causes a slight increase in the rate of attack of aluminum in the stainless steel-aluminum couple system.

Increasing velocities of acid flow cause a decreased rate of attack on stainless steel and an increased rate of attack on aluminum. These effects may be explained on the basis of the removal of reaction and decomposition products of the acid from the metal surface in the case of stainless steel and on the erosion of nitrate film and possibly oxides from the metal surface in the case of aluminum.

Anodic polarization of aluminum in fuming nitric acid indicates two reactions which are dependent on current density. Oxide film formation is prevalent at low current densities while high current densities promote nitrate films. The addition of water to fuming nitric acid alters the polarization characteristics of aluminum.

Acknowledgment

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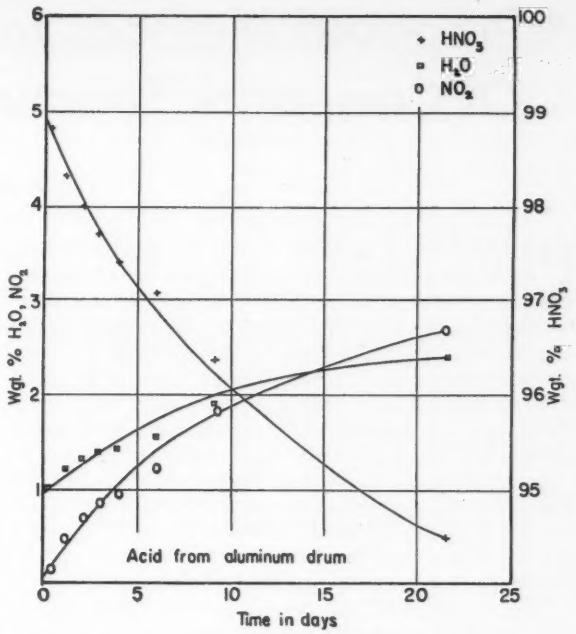

Figure 15—Decomposition of white fuming nitric acid in erosion-corrosion tester at 108 F.

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Proposed Methods for Cathodic Protection Of Composite Structures*

By M. UNZ

PARALLEL pipe lines, cables or similar underground structures can be protected by a common drainage circuit only when they are of the same material and have been imbedded in the ground under similar conditions. As soon as the chemical or physical qualities of the material become unequal or if the structures have been buried in a different way, their direct bonding by the leads of a common protective circuit is liable to produce local corrosion effects.

In order to eliminate this danger, the drainage circuits of heterogeneous components must be kept electrically separated. This is achieved by using entirely independent drainage sources or by applying special blocking circuits, as suggested in this article.

The potential differences between the heterogeneous components must be checked periodically on every composite structure. Because in many cases, for instance as in bore-hole wells, special provisions are required for such measurements, an entire protective scheme may be upset by the lack of adequate testing facilities.

Separation of Drainage Circuits

When a drainage circuit is used for the protection of a composite underground structure, any local electromotive forces created between components of this structure are liable to produce a circulating current that will be superimposed over the current field of the applied system (Figure 1).

As long as the outside current source acts satisfactorily, these local emfs do not affect the protective value of the system, because they have been taken care of by suitable adjustment of the pipe-to-soil voltages. However, when the drainage circuit fails, a corrosion current may develop over the paths marked in Figure 1 with a dotted line, which is liable to be much more harmful than those currents originally assumed.

Considering that despite all maintenance provisions, there is always a chance of disturbances in the protective system, the possibility of such "corrosion short circuits" must be eliminated.

When using galvanic anodes this is achieved simply by grouping them separately, as shown for two pipe lines in Figure 2. It is then easier to control the potential of each pipe and in case of an emf acting betwen the two, there is no metal bond for closing the local circuit. The only path then available for the corrosion current is that over the spread-out resistances of the two anodes connected in series. These resistances will consume the bulk of the available local emf and besides, at the time of anode failures an appreciable increase of the resistance values may be reckoned with, due either to anode decomposition or to high soil resistivity.

The total number of anodes needed for the separate drainage circuits remains practically unaltered. On the one hand there is a saving due to the elimination of circulating currents but on the other hand additional anodes may be required for an adequate disposition of the pipe-to-soil voltages along each line.

Blocking Circuit for Generators

Rectifier elements have been suggested by the author for applied current circuits as a valve against circulating currents.

With a DC generator these elements are inserted into the drainage mains of the structures (Figure 3). The applied current then passes freely, as indicated by the arrows in the diagram, while a circulating current would be blocked by the rectifier element in one of the arms.

The blocking units are not expensive because their reverse voltage is equal to the expected local emf, say 2 volts, only. Their current rating is given by the continuous drainage current of the structure.

With the above attachment the same generator can

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Abstract

Separate current drainage systems or special blocking circuits are required for heterogeneous structures which are closely located to each other. This precaution is essential for the elimination of metallic short-circuit paths between the structures, liable to cause dangerous local corrosion currents when the protective circuit is disturbed.

Galvanic anodes used for the protection of parallel pipe and cable lines must therefore be grouped separately. Applied current generators are equipped with rectifier elements to block circulating currents between the components of the plant protected. AC circuits are fitted with separate rectifier units for each section.

Concentric steel ducting is best completely insulated from the metal body contained in it. Where this is not possible as in the case of bore-hole wells, two separate drainage circuits are required with provision for keeping the potentials of the casing and the inner body on the same level.

A further investigation will be published as soon as experience has been gained with the methods suggested.

★ Submitted for publication January 4, 1954.

safely be applied to any number of heterogeneous structures. The modification is of particular importance for use with intermittently working generators, such as farm lighting sets or wind power units.

Rectifier Circuits

When an AC supply with rectifiers is used, the provision of a separate rectifier in each section is sufficient for the blocking of the circulating currents.

From the diagram in Figure 4 it is obvious that the two rectifier units are connected in parallel for drainage currents flowing in the same direction, but would oppose each other for circulating currents passing in opposite directions.

The use of separate rectifiers for each structure permits independent voltage regulation by means of transformer tappings. This greatly improves the flexibility of the installation and leads to savings in the running charges.

Example 1: Cable Laid in Pipe-Line Trench

A steel tape armoured signal cable has been laid in a common trench with a seamless steel water line. Pipe and cable are well coated. The cable is embedded in a layer of sand, 4 inches thick and located at a distance of not less than 6 inches from the pipe surface.

The assembly is protected by two separate sets of magnesium anodes, as noted in Table 1.

As differences between the pipe and cable potentials are inevitable, a minimum numerical value of U = 0.95 volt to a copper sulfate half-cell, has been assumed for the cable, to provide an additional safety margin. These potential differences will in turn produce circulating currents between the two systems across the spread out resistances of the anodes. As long, however, as the potentials of the resulting current field remain numerically above the prescribed value, the protection is complete.

Assume, for example, a leakage spot on the pipe line at which a local emf appears between the cable armor and the steel pipe. Considering that a corrosion current cannot develop unless at least one of the anode groups is out of order, the outside resistance of the corrosion circuit will exceed the value of a few ohms (Figure 2). A considerable deviation of the structure-to-soil potentials must, therefore, be taking place at this spot, while with a bonding conductor between pipe and cable armor, the dangerous "short-circuit" could not even be detected.

Example 2: Pipe-Line Road Crossing

An 18-inch seamless steel pipe enclosed by a 24-inch duct of the same material crosses under a highway. The assembly must be included in the cathodic protection given the line.

As the pipe is concentrically located inside its ducting, the mere separation of the drainage circuits is insufficient. The potentials of pipe and duct must in this instance be kept permanently equal in order to prevent radial current flow that would inevitably destroy the discharging surface.[1]

This difficulty is overcome by completely insulating the inner pipe from its ducting. Suitable fittings

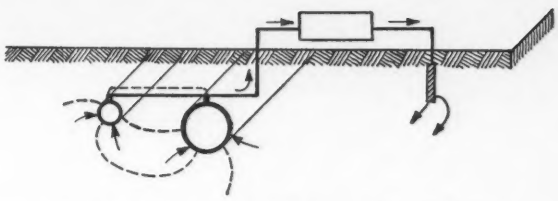

Figure 1—Drainage circuits with common current source.

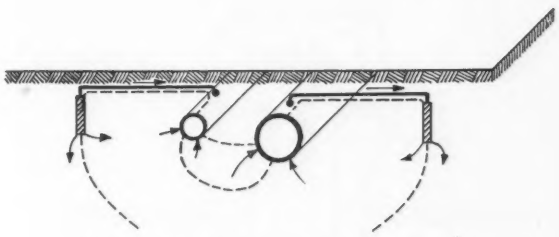

Figure 2—Protection by separate galvanic anodes.

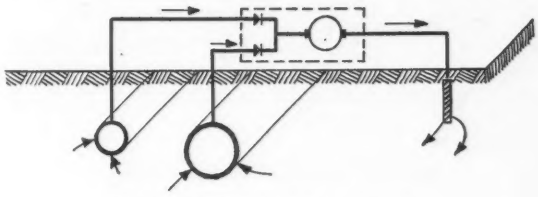

Figure 3—Blocking circuit for generators.

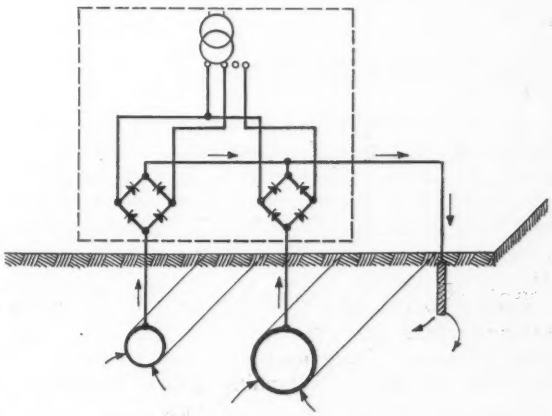

Figure 4—Duplicate rectifier circuit.

Table 1

	Pipe	Cable
Outside diameter over the steel, inches	24	1
Drainage current required, amp/km	1.1	0.09
Number of magnesium anodes, —/km	7 x 22 lb.	2 x 10 lb.
Minimum structure-to-soil voltage, $\|U\|$, expected, volt	—8.85	0.95

are available for this purpose. Inspection pits also can be provided at the ends of the duct for maintenance requirements.

From the economical point of view it appears preferable to abandon the steel ducting altogether and to replace it by reinforced concrete pipe. The ducting does not then worry the corrosion engineer, while

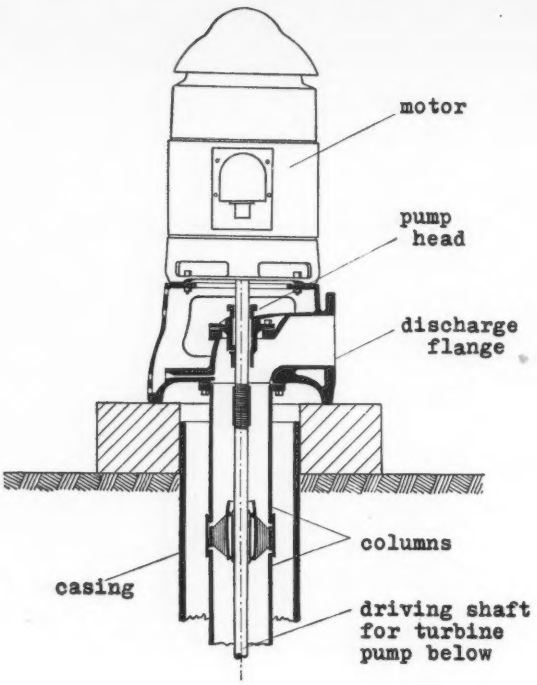

Figure 5—Deep well pump head, assembly.

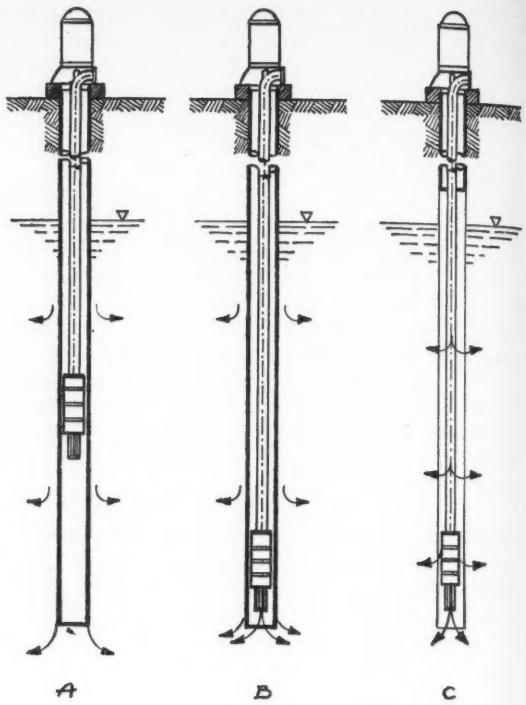

Figure 6—Screening effect of well casing.

the steel pipe line can be protected by its continuous drainage circuit, regardless of any road crossing points.

Example 3: Bore-Hole Pumps

1. General

The well casing with its turbine and delivery piping constitute a typical example of a concentric composite structure subject to corrosion effects. Serious damage has been observed below water level on the outer and inner surfaces of the casing, the columns of the delivery piping, the turbine impellers and the strainers (Figures 5 and 6).

Owing to the difficulties in carrying out reliable measurements on operating wells, the above corrosion phenomena have not been solved until now. The solution reached by attaching galvanic anodes for protection of the turbine and columns[2] is not applicable to cased wells. The anode currents obviously would then use the casing as a bypass, causing additional corrosion at the spots where the current is discharged on its return path to the turbine body.

Three types of wells can be considered with respect to the degree of screening provided by the well casing:

A. The steel casing extending far below the turbine strainer: The pump system is not affected by stray currents in the ground; it may be attached by internal circulating currents only.

B. The turbine is located at the bottom of the casing: Strainer and bottom of the turbine may be attacked by ground currents. Internal circulating currents may be superimposed over the ground current effects.

C. No steel casing under water level: The lower columns and turbine are unscreened.

In the preceding it has been assumed that the well casing is electrically continuous over its entire length. A gap in the casing completely upsets the electrical field of the well. Wherever currents pass through the casing, the lack of continuity will cause serious damage on both the casing and the columns. Such gaps should, therefore, be electrically bridged and tested before equipping the well.

2. Survey Methods

The following voltage measurements can be carried out in a working well with portable probing equipment:

1. Top of casing to water at varying depth, measured by means of half-cell immersed in well.
2. Top of columns to water at varying depths, measured as above.
3. Top of casing and columns to soil, in relation to remote half-cell at ground surface.

A special probing half-cell has been suggested by the author for the above measurements. The cell, about ½-inch in diameter, can be let down into the narrow gap between the columns and casing while the well is running. An elastic centering device keeps the cell at a constant distance from the columns. A calibrated cable or measuring sheave is used for the depth readings, as in standard water level soundings. A valve voltmeter or null-method instrument must be taken for these readings, owing to the relatively high spread-out resistance of the probing cell.

Applied current tests for checking the continuity

of the casing are best carried out on newly drilled wells or with the equipment dismantled for overhaul. The current leads are connected to the casing, with a remote ground bed used for the return. Potential readings are then taken and plotted over the depth.

3. Protection

With the above measuring facilities application of cathodic protection to a running well to protect it against ground currents offers no difficulties. Separate drainage systems are applied to the casing and the delivery columns. The respective potentials are then adjusted and kept equal (Figure 7).

The energy is taken from the AC power supply through a transformer with secondary tappings. The two rectifiers S_c and S_p are rated to suit the current requirements of casing and pump system. A regulating resistance R is provided in one arm for fine adjustment.

In the structural design care must be taken to increase the electrical resistance of the foundation block between casing and pump head. An insulating flange is required at the pump outlet, to prevent line current from entering into the columns of the well.

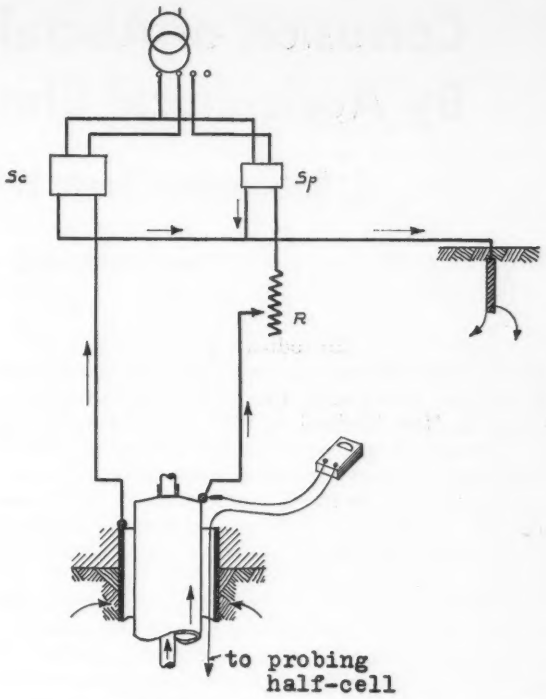

Figure 7—Protection of bore hole pumps.

Conclusions

1. Adjacent structures of the same material which have been embedded in the ground at the same time and under equal conditions can be bonded and protected by one common drainage system.

2. In structures with heterogeneous or differently embedded components each group should be electrically blocked.

The protective circuits are then to be arranged as follows:

a. Galvanic anodes are planted separately for each group.
b. DC generators are fitted with blocking rectifier elements in every group feeder.
c. AC set-ups are provided with separate rectifiers for each group.

3. Concentric metal masses, such as pipes enclosed in steel ducts must be insulated from each other. Alternatively they can be fitted with independent drainage circuits, provided that the potentials of the inner and outer body are kept equal. Bore-hole wells must be protected in this way.

4. The degree of protection attainable for composite structures depends essentially on the measuring facilities available, as illustrated by the examples given in this article.

5. The practical results of the suggested schemes will be discussed when adequate maintenance records are available.

Acknowledgment

The author expresses his thanks to Professor C. A. Stoerk of the Israel Institute of Technology, Haifa, for his valuable advice and to Mr. A. Wiener, Head Irrigation Department of the Water Planning for Israel, Ltd., for permission to publish this paper.

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Corrosion of Aircraft Structural Materials By Agricultural Chemicals*

1. Laboratory Tests With Fertilizer Compounds

By T. MARSHALL[1] and L. G. NEUBAUER[2]

Abstract

Corrosion tests are described, related to the aerial distribution of agricultural chemicals in New Zealand. They indicate that the following compounds are not significantly corrosive towards aircraft structural materials under the conditions obtaining in operating aircraft: agricultural lime, meat-and-bone meal, basic slag, burnt lime.

The following compounds are sufficiently corrosive to make protective coating systems a useful precaution: super compounds, serpentine superphosphate, superphosphate, cobaltized super compound, cobalt sulfate solution, copperized super compound, phosphorized pollard.

The following compounds are significantly corrosive towards one or more important aircraft structural materials: nitrolime, ammonium sulfate, muriate of potash, copper sulfate.

The effects of the above compounds on a few protective coating systems are also given and further tests now in progress are outlined briefly.

Introduction

THE USE OF aircraft for the distribution of agricultural chemicals (so-called "topdressing") started in New Zealand in 1939 with the spreading of experimental batches of biological trace elements.[1] Subsequent progress to aerial topdressing on a tonnage scale has been rapid. Aerial spreading of major tonnages of phosfatic fertilizers and minor amounts of the other bulk fertilizers, pesticides, weedicides, pasture-conditioning trace elements and seeds has been confined almost exclusively to pastoral hill country, where, on economic grounds, inaccessibility favors aerial methods over conventional methods of distribution. The value of these operations may be gauged from their use in one recent year to treat 1.4 million acres of pastoral country of marginal fertility, which could not have been fertilized economically by conventional methods. Their future potential is indicated by an estimate that 13 million acres of pastoral hill country can be economically farmed only with the assistance of aerial topdressing.

Total yearly tonnages of agricultural chemicals distributed by aircraft to date are listed below.

Year ended 31st March	Long Tons Distributed
1950	5,000
1951	45,000
1952	89,000
1953	145,000
1954	195,000

Superphosphate fertilizers (mainly super compound) comprise by far the major proportion of this tonnage, other compounds being distributed on experimental or very small scale only. However, the successful distribution of phosfates is pointing the way now to tonnage distribution of other compounds such as muriate of potash, ammonium sulfate, nitrolime, etc. At the same time availability of aircraft is forcing a gradual changeover from the use of war-surplus "Tiger Moth" steel-and-fabric aircraft to larger and more modern all-metal machines. The tests described below were initiated to assess the corrosion hazards involved in transportation and spreading of these compounds by aircraft, particularly aircraft of all-metal construction, in cases where reliable information was not available in the technical literature.

Granulated fertilizers for aerial distribution are usually carried in hoppers near the cockpit of the aircraft, loaded from above the fuselage and discharged through bottom chutes into the slipstream. During loading and discharge, fertilizer dusts penetrate into practically all parts of the aircraft, with particularly liberal distribution on to and inside the tail structure. The machines operate in both wet and dry weather and frequently are parked overnight in open fields under conditions which permit dew deposition, heavy on external surfaces and light but definite on internal surfaces. Hence, deposits tend to cake hard and are alternately moistened and dried during operations.

Definite, but not extreme, corrosion of Alclad surfaces and deterioration of paint under such phosfatic deposits have been observed in operational aircraft, particularly at lap joints, crevices and inaccessible places from which deposits are difficult to remove during routine overhauls. Rapid deterioration of fabric from contact with phosfates is commonly encountered also. Apart from these occurrences, no serious corrosion has been reported yet in topdressing aircraft, a state of affairs which reflects the marginally corrosive nature of phosfates comprising the bulk distributed to date.

The corrosion tests described below were designed therefore to simulate the exposure conditions which could occur in operating aircraft, thus permitting assessment of corrosiveness of other chemical compounds by comparison with the phosfatic fertilizers whose service behavior is reasonably well known.

★ Submitted for publication, August 9, 1954. This is the first of two papers on this general subject, the second, by a different author, on insecticides, etc., is scheduled to appear in the March, 1955 issue of Corrosion.

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Agricultural Chemicals Tested

Tests were carried out with the following chemicals:

a. Superphosfate.
b. Super compound—a mixture of superphosfate, serpentine and rock phosphate.
c. Serpentine superphosfate—superphosfate mixed with a small amount of ground serpentine rock.
d. Copperized super compound—super compound mixed with a small amount of copper sulfate crystals.
e. Cobaltized super compound—super compound mixed with a small amount of cobalt salt crystals.
f. Copper sulfate solution (300 g/l $CuSO_4.5H_2O$).
g. Cobalt sulfate solution (280 g/l $CoSO_4.5H_2O$).
h. Agricultural lime.
i. Burnt lime.
j. Basic slag.
k. Meat-and-bone meal.
l. Nitrolime—agricultural lime pelletized with ammonium nitrate.
m. Muriate of potash—commercial potassium chloride.
n. Ammonium sulfate.
o. Phosphorized pollard—pollard pelletized with white phosphorus for use as a rabbit poison.

Compounds b and c are most frequently distributed from aircraft. The remainder have been used on a small scale or in experimental batches only. Compounds a, d, e, l, m and n are potentially important for future aerial distribution on a tonnage scale.

Structural Materials Tested

Materials in Table 1 were exposed in the humidity-cabinet tests, in contact with each of the above agricultural compounds. These are typical materials used or likely to be used in the construction of topdressing aircraft.

Preliminary tests on all the aluminum alloys in the table ensured that none were in the heat-treatment condition susceptible to intergranular corrosion. Galvanized steel was included in the tests because it is commonly used for construction of hoppers in aircraft. Fabrics and plywoods are used in "Tiger Moth" topdressing aircraft.

Exposure of alloys with paint and other surface treatments permitted assessment of the protective value of these treatments.

Metal samples were exclusively in the sheet form to simplify test procedures and to simulate the form in which the alloys are employed in typical topdressing aircraft.

Test Procedure

The primary aim of the test was to simulate as closely as practicable and in a reproducible manner the worst atmospheric exposure and contamination conditions obtaining in operating topdressing aircraft, thus comparing the corrosive actions of various chemical contaminants on typical aircraft structural materials under conditions representative of field exposure. Excessive laboratory acceleration of the tests was deliberately avoided.

To this end, specimens of typical structural materials in contact with each of the agricultural chemicals were exposed to the alternate dew-deposition and drying cycles of a humidity cabinet. Subsequent comparison of corrosion in the cabinet with corrosion of and by the same materials in topdressing aircraft has, in fact, shown a very satisfactory correlation, with no evidence of undue acceleration of attack under the humidity-cabinet conditions.

TABLE 1—Structural Materials Tested

[1]—Maximum [2]—Minimum Rem.—Remainder

MATERIAL	NOMINAL COMPOSITION PERCENT														Nearest Equivalent American Specification
	C	S	P	Mn	Mg	Cu	Fe	Si	Al	Ca	Ni	Ti	Cr	Zn	
1 Mild steel BSS No. 3S3	0.20-0.25	.05[1]	.05[1]	0.60[1]			Rem.	0.30[1]			0.30[1]				SAE 1020
2 Galvanized steel, commercial hot-dip galvanized sheet	Average zinc coating thickness—.001-inch														
3 Pure aluminum, BSS No. 2L16							1.0[1] (Fe + Si 1.75[1]	1.0[1]	98.0[2]						Alcoa 2S
4 Clad aluminum alloy (core); DTD 390 (Alclad) (cladding)				0.3-1.2	0.6-1.8	3.5-5.0	0.7[1]	0.7[1]	Rem. 99.5[2]						Alcoa Alclad 24S
5 Clad aluminum alloy DTD 390 sprayed with one coat of zinc chromate primer	Zinc chromate primer to DTD 63A														As above
6 Duralumin, BSS 5L3				0.4-0.7	0.4-0.8	3.5-4.5	0.7[1]	0.7[1]	Rem.				0.3[1]		Alcoa 17S
7 Duralumin BSS No. 5L3 anodized	Anodized by Canning's aircraft process* using a chromic acid bath														As above
8 Aluminum alloy, BSS NS4				0.5[1]	1.75-2.75	0.15[1]	0.75[1]	0.6[1]	Rem.			0.2[1]	0.5[1]		Alcoa 52S
9 Magnesium alloy, DTD No. 118A				1.0-2.0	Rem.	0.02[1]	0.03[1]	0.02[1]	0.05[1]	0.02[1]	0.005[1]			0.03[1]	Dowmetal M.
10 Magnesium alloy DTD 118A with selenide surface treatment	Panels degreased and brush-coated with 10 percent celenious acid solution to give a permanent brown-black coating, De Havilland Process specification 167/1 Para. 6.														
11 Spruce strips lap-jointed with casein glue	Spruce to DTD No. 36B, Aerofix casein glue to BSS 4V2														
12 Spruce strips lap-jointed with Beetle cement	Spruce to DTD No. 36B, Beetle cement to BSS 1204														
13 Doped aircraft fabric	4-ounce linen to DTD No. 540														
14 Plywood strips	To BSS V3														
15 Mild steel, for nitrate stress—corrosion tests only	0.06	0.04	0.02	0.31		0.10		0.04			0.05		0.01		SAE 1006

* See Reference No. 6, 7 at end of article.

Test-pieces of all the following types were used in contact with each of the various chemicals:

1. 6½ by 4½-inch panels of alloys 1, 2, 3, 4, 6, 8 and 9 in Table 1, machined from sheet stock with due regard to thickness, surface finish, rolling direction, etc. These panels were cleaned, degreased and weighed before exposure.

2. 6½ by 4½-inch panels of alloys with surface treatments listed as numbers 5, 7 and 10 in Table 1, included for assessment of the protective value of the surface treatments.

3. Rivetted lap-joints (simulating the rivetted laps in aircraft structures) of the sheet alloys, 1, 2, 3, 4, 6, 8 and 9, in Table 1, the mating surfaces of the laps being packed (or sprayed) with the various chemicals before assembly, as a test for possible acceleration of corrosion under crevice conditions.

4. Stress-corrosion test-pieces of alloys 1, 3, 4, 6, 8 and 9 in Table 1, following the horse-shoe pattern described by Franks, Binder and Brown[2] and included in the tests as a check on the possible occurrence of stress-corrosion cracking. In addition, test pieces of a mild steel of known susceptibility to nitrate stress-corrosion were exposed in contact with nitrolime (alloy number 15 in Table 1).

5. Aircraft fabric, mounted on 12 by 6-inch spruce frames and doped on one surface as in normal aircraft practice, included for assessment of any deterioration of the fabric due to contact with the chemicals.

6. Glued-joint tensile test-pieces 1 inch wide by 8 inches long, fabricated from matched pairs of 1 by ⅛ by 4½-inch spruce strips glued together at a 1-inch overlap with "Beetle" cement and four with casein glue were exposed in contact with each agricultural compound to assess deterioration in joint strength.

7. Strips of aircraft plywood, included as a test for separation of ply under the action of the agricultural chemicals.

Contact of the test pieces with the agricultural chemicals was facilitated by loading them in wooden trays for exposure in the cabinet. Each test tray carried a complete set of the above test pieces in contact with one chemical, an additional control tray carrying an identical set of test pieces without any chemicals, for comparison purposes.

In all test trays the glued-joint, stress-corrosion and plywood test pieces were placed on and covered with (or sprayed with) the agricultural chemicals, while in the control tray these test-pieces were simply placed on the tray floor. In all trays the crevice-corrosion test assemblies stood in simple racks with the lap-joints vertical, control assemblies carrying no chemicals in the lap-joints.

To facilitate migration of moist and dry air to both surfaces, the 6½ by 4½-inch panels and frame-mounted fabric panels in the control tray were placed flat on a carpet of open-textured felt. In the test trays the panels were similarly laid flat above felt carpets, but with ⅛-inch layers of the solid chemicals interposed between panels and felt and a further layer of chemicals laid over the panels.

In the case of the chemical solutions, the panels were sprayed with the liquids before being placed on the felt.

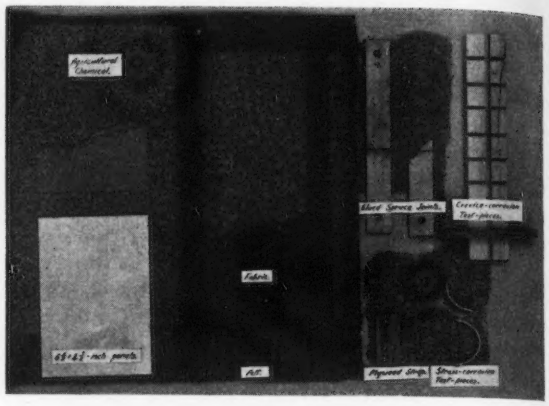

Figure 1

In this way both horizontal surfaces of each test panel were exposed to migrating moist and dry air whilst being simultaneously in contact with the agricultural chemicals. Test specimens were arranged to avoid contact between dissimilar metals and to minimize contamination by corrosion products from other assemblies. Figure 1 illustrates the various types of test-pieces and their arrangement in the trays. Specimens have been uncovered partly to show the relative positions of felt, chemical and test-pieces.

Arrangement of Test-Pieces in Trays

Apart from the set of control test specimens in the humidity cabinet, an identical set of master control specimens was stored in a dry cabinet during the tests. These master controls received the identical pre-treatment, cleaning and final weight-loss and tensile testing as used on other test specimens.

After loading with test-pieces and chemicals the trays were positioned in the humidity cabinet in tiers, spaced to facilitate the forced circulation of air over all tray surfaces. Particular care was observed to avoid contamination of specimens with chemicals from other trays, the tray with phosphorized pollard being initially weathered out-of-doors for three days until all phosphorus fuming had abated.

Operation of the humidity cabinet then followed the convenient weekly cycle:

1. 24 hours' operation with forced circulation of air at 100 percent relative humidity.
2. 24 hours' operation with forced circulation of dry air.
3. 24 hours' humidity period as under 1.
4. 24 hours' drying period as under 2.
5. 8 hours' humidity period as under 1.
6. 64 hours' drying period as under 2.

The above cycle was repeated over a period of 121 days, all test-pieces being exposed for 121 days, except those of pure aluminum BSS 2L16 which were inserted late and received only 93 days' exposure.

Tests with a moisture detector indicated that, with the above operational sequence, all test-piece surfaces in contact with non-hygroscopic agricultural chemicals were subject to alternate drying and dew deposition by the alternate diffusion of dry and humid air through the layers of chemicals. However, owing to

TABLE 2—Summary of Corrosion Test Results for Metal Panels

Agricultural Chemical	Average Corrosion Rates, Corrosion Characteristics, Losses of Tensile Strength (LTS) and Other Data *For: Mild Steel BSS 3S3	Galvanized Steel	Pure Aluminum BSS 2L16	Clad Duralumin DTD 390 (Alclad)	Duralumin BSS 5L3	Al-Mg Alloy BSS NS4	Magnesium DTD 118A
Superphosfate	Gu3** .0026 6%	Gu2 .000 Zinc not penetrated	M711 .0001 low	M711 .0001 low	M711 .0002 4%	M711 .0001 4%	Gu2 .0009 3%
Super compound	Gu3 .0012 low	Gu1 .000 Zinc not penetrated	M711 .0000 low	M711 .0000 low	M711 .0000 low	M711 .0000 2%	Gu2 .0005 2%
Serpentine superphosfate	Gu3 .0015 low	Gu1 .000 Zinc not penetrated	M611 .0000 low	M711 .0000 low	M711 .0000 low	M511 .0000 low	Gu2 .0003 low
Copperized super compound	Lu343 .0007 low	Le242 .000 Zinc penetrated locally	M222 .0000 low	Lu221 .0000 low	M222 .0000 low	M231 .0000 3%	M232 .0007 5%
Cobaltized super compound	M511 .0007 low	Lu232 .000 Zinc not penetrated	M711 .0000 2%	M711 .0000 low	M711 .0000 low	M711 .0000 3%	M511 .0007 2%
Copper sulfate solution	Gu4 .0166 44%	Gu3 .003 Zinc partly stripped	M322 .0004 low	Lu231 .0009 7%	M322 .0008 14%	M322 .0008 13%	M322 .0049 24%
Cobalt sulfate solution	W421 .0012 3%	Lu411 .000 Zinc penetrated locally	M412 .0001 low	Lu221 .0000 low	M511 .0001 low	M322 .0000 low	M511 .0021 4%
Agricultural lime	Gu1 .0001 low	Gu1 .000 Zinc not penetrated	Nil .0000 low	Nil .0000 low	Nil .0000 low	Gu1 .0000 2%	Gu1 .0001 low
Burnt lime	Nil .0000 low	Nil .000 Zinc not penetrated	Nil .0000 low	Nil .0000 low	Nil .0000 low	M311 .0000 low	Gu1 .0000 2%
Basic slag	Nil .0000 low	Nil .000 Zinc not penetrated	Nil .0000 low	Nil .0000 low	Nil .0000 low	Nil .0000 low	Gu1 .0000 2%
Meat and bone meal	Nil .0000 low	Gu1 .000 Zinc not penetrated	Nil .0000 low	Nil .0000 low	Nil .0000 low	Nil .0000 low	Nil .0000 low
Nitrolime	Lu354 .0078 30%	Gu4 .012 Zinc completely stripped	Nil .0000 low	Nil .0000 low	Nil .0000 low	Gu1 .0000 2%	Gu5 .0330 57%
Muriate of potash	Gu4 .0144 71%	Gu3 .004 Zinc partly stripped	M323 .0001 low	M711 .0004 low	M423P1 .0026 56%	M222 .0001 4%	M334P1 .0081 41%
Ammonium sulfate	Gu4 .0062 11%	Gu4 .010 Zinc completely stripped	M311 .0002 low	Lu241 .0008 low	M522 .0007 17%	M323 .0002 5%	Gu5 .0340 52%
Phosphorized pollard	Gu2 .0010 low	Gu2 .000 Zinc not penetrated	Nil .0000 low	Lu141 .0002 2%	M222 .0002 21%	M223 .0001 9%	Gu3 .0010 4%
Controls (no agricultural compound)	Gu1 .0002 low	Gu1 .000 Slight "white rusting"	Nil .0000 low	Nil .0000 low	Nil .0000 low	Nil .0000 low	Gu1 .0002 2%
Accuracy limits for LTS determinations	2.4%	.....	1.8%	1.6%	2.8%	2.0%	1.6%
Initial thickness of test panels, inches	.042	.032	.028	.031	.036	.037	.064
Exposure time, days	121	121	93	121	121	121	121

Note: [1] Rate figures for the composite alloys, (galvanized steel and alclad) refer to rates of attack on the surface alloys only.

[2] Loss-of-tensile-strength figures do not correlate perfectly with average corrosion-rate figures. This is due to unavoidable variations in initial thickness of samples, to use of composite alloys in the tests and to dependence of strength losses on type and distribution as well as average rate of corrosion.

* The order of data is: Top—Champion's shorthand classification type: Middle, loss in inches per year: Bottom, loss of tensile strength.

** Champion shorthand classification abbreviations: Gu—Uneven general corrosion; Le—Even semi-local corrosion; Lu—Uneven semi-local corrosion; W—Wide, shallow pits; M—Pits of medium depth; P—Perforation of specimen; Nil—No visible corrosion. Numerals in the shorthand indicate depth, frequency and other characteristics of the observed corrosion.

the long diffusion path through the felt, undersurfaces of the 6½ by 4½-inch panels were subject to abbreviated humidity periods and showed slightly less corrosion than the upper surfaces. Hygroscopic and deliquescent chemicals remained moist right through the cabinet cycle.

Results of the tests were assessed by the following methods:

1. On the 6½ by 4½-inch panels of bare alloys, assessment of corrosion rates (in inches per year) followed the American Society for Testing Materials recommended procedures,[3] panels being cleaned by methods described by Uhlig.[4] Subsequent examination under a stereoscopic microscope then permitted classification of the types of corrosion occurring on the panels, according to the scheme evolved by Champion.[5] Finally the panels (excepting those of galvanized steel) were machined into tensile test-pieces for determination of losses of tensile strength due to corrosion. These determinations followed procedures recommended by Champion,[5] using 4 or 6 replicate tensile test-pieces.

2. With the 6½ by 4½-inch metal panels carrying surface treatments, assessment of results was based on visual examination of the washed and lightly scrubbed surfaces.

Figure 2—Corrosion of aluminum BSS 2L16 by superphosfate, illustrating the characteristic pitting of aluminum alloys by the phosfate fertilizers. X 18.

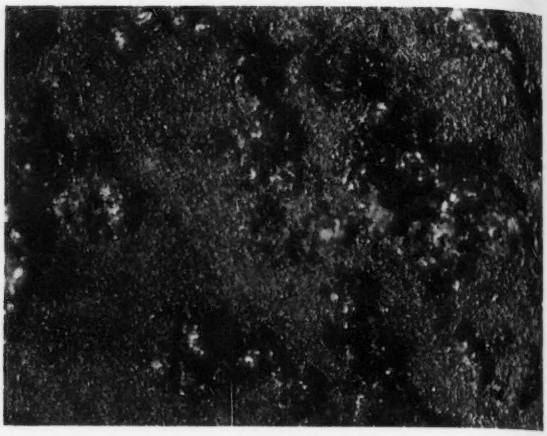

Figure 3—Corrosion of Duralumin BSS 5L3 by muriate of potash, typifying the severe pitting of aluminum alloys by this compound. X 18

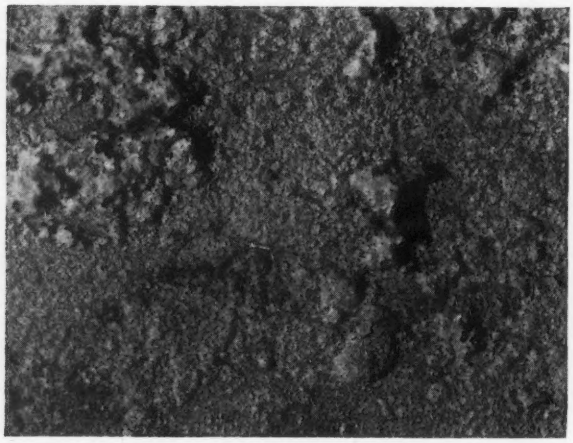

Figure 4—Corrosion of aluminum-magnesium alloy BSS NS4 by copper sulfate solution, illustrating the severe pitting of aluminum alloys by this solution. X 18.

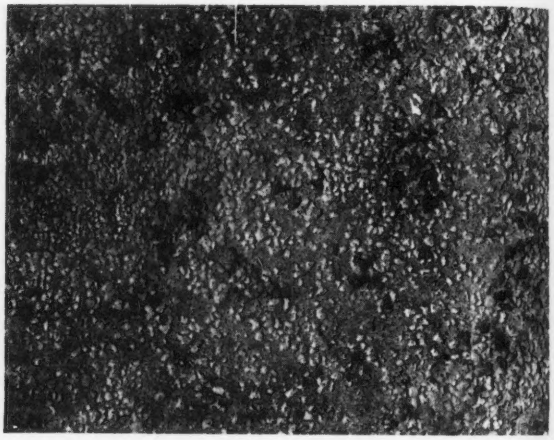

Figure 5—Corrosion of clad Duralumin DTD 390 by ammonium sulfate, showing typical wide, shallow pitting of cladding layer which demonstrates the sacrificially protective action of the cladding towards the underlying Duralumin core. X 18.

3. The crevice-corrosion test-pieces were disassembled by drilling out the rivets, the mating plates of the joints being cleaned as in 1 above. Visual comparison of the cleaned mating surfaces with the surfaces of corresponding 6½ by 4½-inch panels of the same alloys then revealed any marked acceleration of corrosion under the crevice conditions.

4. Assessment of stress-corrosion test results took the form of releasing stresses on the horseshoe test-pieces, cleaning them by methods as in 1 above and examining the tensile-stressed surfaces for cracks with a stereoscopic microscope.

5. Effects of chemicals on the doped fabric panels were assessed by washing the panels in water and then cutting the fabric into strips parallel to the weft for tensile testing, to determine loss of strength resulting from action of the chemicals. Again 4 or 6 replicate test strips from each panel were used.

6. Tensile tests on the quadruplicate glued-joint test-specimens followed the general procedure given in BSS 647, results of any tests where oblique fracture occurred through the spruce timber being discarded.

7. Plywood strips were simply examined visually for separation of ply.

Results of Tests

During placement of test-pieces into the humidity cabinet, bare magnesium panels were seen to react visibly and rapidly with copper sulfate and cobalt sulfate solutions. Nitrolime used in the tests was extremely deliquescent, ammonium sulfate and muriate of potash being hygroscopic and caking hard on the specimen surfaces.

The following compounds became distinctly acid during the tests (approximately pH 2): Copperized super compound, cobaltized super compound, superphosfate, super compound, serpentine superphosfate, phosphorized pollard.

The following chemicals became weakly acid (approximately pH 4): Nitrolime, ammonium sulfate.

The burnt lime, after initial slaking during the first dew cycle, remained slightly alkaline (approximately pH 10).

All other compounds remained essentially neutral.

Panel Test Results

Corrosion rates, characteristics and strength-loss results are summarized in Table 2. Average rates of attack (except those for galvanized steel) are given to the nearest .0001-inch per year, which is well within the accuracy limits of the method of measurement (any rates less than .00005 ipy being denoted .0000 ipy). The corrosion rates for galvanized steel are given to the nearest .001 ipy, because larger errors were introduced in this case during the cleaning process.

Losses of tensile strength due to corrosion (abbreviated LTS) for all alloys except galvanized steel are included in the table, the term 'LTS low' indicating a loss of strength within the accuracy limits of determination given at the foot of the table.

For comparison purposes the types of corrosion which occurred on the panels are classified according to the shorthand system of Champion.[5]

Characteristic forms of pitting corrosion are illustrated by the photomicrographs in Figures 2-5.

Results of Crevice-Corrosion Tests

No severe crevice corrosion occured in the tests. In three cases (steel with ammonium sulfate, duralumin with muriate of potash, magnesium with muriate of potash) slight visible acceleration of corrosion occurred in the crevice tests. In all other cases corrosion under crevice conditions was of the same order as attack on the upper surfaces of the 6½ by 4½-inch panels.

Stress-Corrosion Tests

No stress-corrosion cracking was observed in the non-ferrous alloys tested. Since stress-corrosion cracking of mild steels is common in boiling ammonium nitrate solution, some auxiliary tests were carried out in boiling suspensions of nitrolime. Horseshoe-type stress-corrosion test-pieces of mild steel to BSS 3S3, stressed beyond the elastic limit, did not crack after 32 hours in boiling 50 percent nitrolime suspension. Similar test-pieces of a susceptible mild steel of composition listed above, cracked after less than 24 hours in the boiling solution. Test-pieces of steel to BSS 3S3 showed no cracking after three months' exposure to moist nitrolime at room temperature but were severely corroded. Test-pieces of the susceptible mild steel under similar conditions showed slight cracking as well as severe surface corrosion.

Investigations on stress-corrosion cracking of aircraft steels by nitrolime were not carried further because the effects of temperature and steel composition alone afford scope for a major investigation.

Results of Tests on Surface Protective Treatments

The behavior of chromate primer on Alclad, anodizing on Duralumin and selenide surface treatment on magnesium, are summarized in Table 3.

The painted surfaces exposed to superphosfate, super compound and serpentine superphosfate, all showed a very characteristic blue-green staining at points of film break-down. This stain tinted the water used for washing the panels and probably was caused by decomposition of the chromate pigment in the paint film. Blue-green stains noted at lapped skin-joints of painted all-metal top-dressing aircraft are believed to be of similar origin.

Results of Tests on Plywood

No visible deterioration of the plywood and no separation of ply occurred in the tests.

Strength-Loss Tests on Fabric and Glued Joints

Percent losses of tensile strength of doped fabric, of Beetle-cement and casein-glue joints are detailed in Table 4.

A wide scatter of the strength-loss results for doped fabric and glued joints limits the conclusions that can be drawn from Table 4. However it is evident that doped fabric, exposed to the dew cycle

TABLE 3—Summary of Test Results on Surface Protective Treatments

Agricultural Chemical	Effect on Chromate Primer Film On Clad Duralumin, DTD 390	Effect on Anodic Film on Duralumin BSS 5L3	Effect on Selenide Coating on Magnesium DTD 118A
Superphosfate	Complete disintegration of film by microscopically fine blistering. Green staining of panel.	General penetration of the film at numerous closely-spaced points.	No visible damage
Super compound	Partial disintegration as for superphosfate but not so severe. Green staining of panel.	General penetration of the film at numerous closely-spaced points.	No visible damage.
Serpentine superphosfate	Partial disintegration of film by microscopically fine blistering, similar to super compound. Green staining of panel.	General penetration of the film at numerous closely-spaced points.	No visible damage.
Copperized super compound	No visible damage.	General penetration of the film at numerous closely-spaced points.	Local penetration of coating at a number of points.
Cobaltized super compound	Film stripped from half panel area by pinpoint penetration followed by lateral corrosion.	General penetration of the film at numerous closely-spaced points.	Local penetration of coating at a number of points.
Copper sulfate solution	Widespread blistering with active corrosion of metal under blisters.	Film stripped at numerous patches.	General destruction of coating.
Cobalt sulfate solution	No visible damage.	Film penetrated at a few points.	General destruction of coating.
Agricultural lime	No visible damage.	No visible damage.	No visible damage.
Burnt lime	No visible damage.	No visible damage.	No visible damage.
Basic slag	No visible damage.	No visible damage.	No visible damage.
Meat and bone meal	No visible damage.	No visible damage.	No visible damage.
Nitrolime	Film thinning occurred, but no complete penetration.	No visible damage.	General destruction of coating.
Muriate of potash	Few small blisters, film otherwise sound.	Anodizing penetrated locally at numerous points.	General destruction of coating.
Ammonium sulfate	Fine blistering and partial break-down of the film with corrosion of exposed metal.	Anodizing penetrated locally at numerous points.	General destruction of coating.
Phosphorized pollard	Film softened and bleached, complete penetration at a few points.	No visible damage.	Local penetration of coating at a number of points.
Controls (no agricultural compound)	No visible damage.	No visible damage.	No visible damage.

alone, showed a slight loss in strength, probably due to rotting in the high-humidity conditions. Many chemicals appeared to retard this strength loss, whilst others caused definite acceleration of strength loss. Moisture has had a dominant effect on strength loss of casein-glued joints, the effect of agricultural chemicals in all cases being less than that of the dew cycle alone.

Discussion

The tests lead to the following general conclusions regarding corrosiveness of the various chemicals and the value of the protective systems, under the operating conditions of top-dressing aircraft. Results for super compound have been taken as a criterion of corrosiveness because this material comprises the bulk tonnage distributed from aircraft to date and examination of such aircraft has revealed relatively slight attack on bare steel, Duralumin and Alclad surfaces.

1. Superphosfate

Corrosion of steel, Duralumin, magnesium and the aluminum-magnesium alloy by this fertilizer was of a significantly higher order than corrosion by super compounds. Pitting of pure aluminum and Alclad was quite distinct but had not progressed far enough to cause significant strength losses and, in the case of Alclad, had not stripped the cladding over appreciable areas. Galvanizing on steel and the selenide coating on magnesium exhibited high resistance to superphosfate but the chromate primer on Alclad and anodizing on Duralumin were of no great protective value.

Superphosfate had no significant effect on either of the glued joints but doped fabric suffered a severe loss of strength.

The corrosive action of superphosfate is sufficient to warrant the protective coating of metal surfaces in aircraft distributing this fertilizer.

2. Super Compound

Attack by this fertilizer is taken as a criterion of corrosiveness in the tests, because aircraft used in its distribution have exhibited definite but slight pitting of exposed metal surfaces, the pitting being of a very characteristic form on aluminum alloys. In these tests, super compound caused the same slight but characteristic pitting of aluminum alloys, thus giving a measure of confirmation of the validity of the test method.

Slight general attack occurred on steel and magnesium. Galvanizing on steel and the selenide coating on magnesium showed excellent resistance to super compound; chromate primer on Alclad and anodizing on Duralumin were only partly effective as corrosion barriers. Super compound did not appreciably affect either of the glues but the fabric was damaged almost as much as by straight super phosfate.

In spite of the low strength-losses in the tests, the distinct pitting and slight general attack on metal surfaces by super compound suggest that it would be an economically useful precaution to maintain protective coatings on aircraft metal surfaces exposed to this compound.

3. Serpentine Superphosfate

Test results with this fertilizer were almost identical to those with super compound and similar remarks apply. Beetle cement showed an appreciable loss of strength, whilst casein glue was not significantly affected.

4. Copperized Super Compound

In spite of the copper sulfate contained in this mixture, it caused significant attack on only magnesium and the aluminum-magnesium alloy. Attack on the other alloys in comparison with that of super compound was slight. The marked contrast between slight corrosion by copperized super compound and the severe attack by copper sulfate solution (see below) may be due to fixation of copper as insoluble salts by the super compound.

Galvanizing on steel, anodizing on Duralumin and the selenide coating on magnesium were partly effective as corrosion barriers and the chromate primer on Alclad showed an unexpectedly high resistance to copperized super compound.

The deterioration of Beetle cement was appreciable, while casein glue and doped fabric were not significantly affected.

It is obvious that the use of copperized super compound instead of copper sulfate solution represents the better method of distributing copper as a trace element from top-dressing aircraft. Owing to the possibility of copper precipitation on metal surface, it would be a wise precaution to paint all such surfaces before distribution.

5. Cobaltized Super Compound

In comparison with super compound, cobaltized super compound was not significantly corrosive towards the alloys tested. As with super compound the chromate primer showed poor resistance; anodizing on Duralumin and the selenide coating on magnesium were only partly protective, but galvanizing on steel gave a high degree of protection.

There was little or no attack on the glued joints or doped fabric by this compound.

Of the two methods of distributing cobalt as a

TABLE 4—Summary of Test Results for Doped Fabric and Glued Spruce Lap Joints

Agricultural Chemical	Percent Loss of Strength in Doped Fabric	Beetle Cement Joints	Casein Glued Joints
Superphosfate	40	5.5	—2*
Super compound	33.5	10.5	0.5
Serpentine superphosfate	2	22.5	—6.5*
Copperized super compound	2	20	—3*
Cobaltized super compound	16	5.5	12
Copper sulfate solution	15	45	17
Cobalt sulfate solution	6.5	15	17.5
Agricultural lime	14	3.5	—0.5*
Burnt lime	—7.5*	7	1
Basic slag	6.5	11	—1*
Meat and bone meal	3	3.5	1.5
Nitrolime	—15*	8	12
Muriate of potash	—3*	0	8.5
Ammonium sulfate	—6.5*	11	3
Phosphorized pollard	21.5	7.5	6.5
Controls (no agricultural compound)	8.5	—3*	19.5

* Gain.

trace element from aircraft (as cobalt sulfate solution and as cobaltized super compound) the latter is considered preferable. Painting of metal surface as for distribution of copperized super compound would again be desirable.

6. Copper Sulfate Solution

In comparison with super compound this solution proved seriously corrosive to all of the alloys tested and all protective systems proved to be very poor corrosion barriers.

Serious deterioration of Beetle cement occurred but casein glue and doped fabric were not significantly affected.

Distribution of this solution from aircraft of any type would be highly inadvisable, especially since copper deposited on the metal surfaces by contact with the solution cannot be removed by any normal cleaning processes and when deposited continues to be active in accelerating corrosion under damp conditions.

7. Cobalt Sulfate Solution

Attack on steel and magnesium by this solution was sufficient to indicate the necessity of protective coatings. Attack on the other alloys tested was not severe. The selenide coating on magnesium proved ineffective as a corrosion barrier, galvanizing on steel and anodizing on Duralumin were only partly effective but the chromate primer on Alclad showed good resistance to the solution.

The cobalt sulfate solution had a deleterious effect on Beetle cement but casein glue and doped fabric were not significantly affected.

8. Agricultural Lime, Burnt Lime, Basic Slag, Meat-and-Bone Meal

With all of these fertilizers less corrosion occurred than with super compound and in most cases no attack could be detected. Similarly these compounds did not cause serious deterioration of the protective systems, glued joints, plywood or fabric. Although exposure conditions in aircraft (where frequent applications of fresh unslaked lime might occur) might be slightly more severe than the test conditions with burnt lime, it is considered that distribution of these fertilizers (including burnt lime) involves no risk from the corrosion viewpoint.

9. Nitrolime

This fertilizer caused severe corrosion of steel and magnesium, but gave no detectable attack on the aluminum alloys. Galvanizing on steel and the selenide coating of magnesium showed no useful protection against attack, whilst chromate primer proved fairly resistant and anodizing on Duralumin proved highly resistant to the compound. Nitrolime had no significant effect on the glued joints and doped fabric.

Nitrolime consists of a deliquescent mixture of calcium carbonate and ammonium nitrate. Because ammonium nitrate solutions are known to cause stress-corrosion cracking of steels,[6] it is possible that nitrolime could cause brittle fracture of stressed steel structures in topdressing aircraft, as indicated by subsidiary stress-corrosion tests described above. Some characteristics of this type of corrosion cracking may be noted:

1. Mild steels, particularly those containing less than 0.2 percent carbon are more susceptible to stress-corrosion cracking in nitrate solutions than are the higher-carbon steels, although cases of failure of high carbon steel have been reported.
2. Stress-corrosion cracking of steel occurs more commonly in hot nitrate solutions than in cold solutions (cases of cracking in cold dilute solutions have been reported).[6] The influence of temperature on cracking has not been critically investigated.
3. For most steels there appears to be a definite value of steady-state stress below which stress-corrosion cracking does not occur. This stress value is usually a large proportion (70 percent or more) of the yield stress.
4. Steels of different composition vary markedly in their susceptibility to nitrate stress-corrosion cracking.

In view of the serious corrosion experienced in these tests and the reported occurrence of stress-corrosion cracking of steel by nitrate solutions, the distribution of nitrolime from aircraft involves risks of dangerous failure of stressed steel members such as control cables, engine mountings, etc. Protective coatings, owing to their susceptibility to local mechanical damage are not considered adequate safeguards against stress-corrosion cracking.

The limitations in present knowledge of nitrate stress-corrosion of steel, especially regarding the precise influence of temperature and alloying elements, suggest that a more detailed test program on a comprehensive range of aircraft steels would be required to assess the risk of stress-corrosion cracking by nitrolime in top-dressing operations. Until more detailed information is available, the distribution of this fertilizer from aircraft must be considered highly inadvisable.

10. Muriate of potash

This chemical proved severely corrosive to most of the alloys tested. Attack on the pure aluminum, though not severe, was quite distinct and attack on Alclad was more serious than is indicated by the loss-of-strength figures, because, after destruction of the cladding over wide areas, subsequent corrosion of the exposed core would approach the rates experienced with Duralumin. Galvanizing on steel and selenide coating of magnesium were of negligible protective value, anodizing was partly protective to Duralumin, but chromate priming gave almost complete protection to Alclad. The glued joints and doped fabric suffered no significant loss of strength from contact with the chemical.

From the tests it is concluded that muriate of potash, if distributed at all from aircraft, would require precautions to avoid corrosion. Surface protection of all structural alloys would be essential, e.g. by painting exposed surfaces and by frequent inspection and by careful maintenance of the protective coating on internal, external and faying surfaces.

11. *Ammonium sulfate*

This chemical also proved seriously corrosive to most of the alloys tested. Attack on Alclad was again more serious than the strength-loss figures indicate, because the cladding was destroyed over significant areas and corrosion of the exposed core soon would have given strength-loss rates approaching those experienced with Duralumin. Pure aluminum showed the highest resistance to this compound but even with this metal the corrosion was quite significant. Galvanizing on steel and selenide coating on magnesium showed no useful resistance to ammonium sulfate and anodizing and chromate priming gave only partial protection to aluminum alloys.

Ammonium sulfate had a slight effect on Beetle cement but caused no significant deterioration of casein glue or doped fabric.

Results indicate that ammonium sulfate could cause serious corrosion in aircraft. If used at all for aerial top-dressing it should be prevented from attacking aircraft metal structures by carefully applied and maintained protective coatings, as mentioned under the discussion on muriate of potash.

12. *Phosphorized pollard*

Significant corrosion by this compound occurred on Alclad, Duralumin, the aluminum-magnesium alloy and magnesium but corrosion of steel and pure aluminum was not severe. Galvanizing on steel showed a high resistance to phosphorized pollard. All other protective coatings tested were only partly effective as corrosion barriers.

Neither of the glues was appreciably affected by this compound but doped fabric showed a slight loss of strength.

Although it fumes badly, phosphorized pollard in the form of pellets is not susceptible to dusting and not likely to contaminate the aircraft structure badly. Careful maintenance of protective paint coatings should prove entirely adequate in avoiding corrosion troubles in aircraft distributing this rabbit poison.

General Remarks

A few general remarks may be made about behavior of the various alloys and protective coatings in the tests. Results clearly indicate the protective value of cladding on Duralumin and the superior corrosion resistance of high-purity aluminum over alloys of lower purity. Magnesium proved so susceptible to corrosion that protective coatings would be essential on magnesium-alloy components of top-dressing aircraft (as is normal in aircraft constructional practice) and careful inspection and maintenance of such coatings would be necessary also.

The hygroscopic and deliquescent natures of ammonium sulfate, muriate of potash and nitrolime undoubtedly had an important influence in facilitating corrosion by these compounds.

In spite of the disappointingly poor resistance of the chromate primer to the important superphosfate compounds, it is considered that paint systems represent an essential and practical method of minimizing corrosion damage in top-dressing aircraft. Even if they act as effective corrosion barriers for only a few months, the ease with which damage can be detected and repairs effected, make paint systems eminently practical as safeguards against corrosion. The frequency with which damage to paint films at rivetted lap joints occurs in operational aircraft and the tendency of agricultural chemicals to accumulate along such joints, indicates that the use of lap-sealing compounds in top-dressing aircraft would be highly desirable. Multi-coat paint systems undoubtedly would show better performance than the single coat of chromate primer used in the tests and paints of other types may show much higher resistance to specific compounds.

The tests confirm the experience of operators that super compound severely affects fabric, frequent replacement being necessary.

These corrosion tests were not designed to indicate the effects of agricultural compounds on the fatigue life of aircraft structures. It may be regarded as axiomatic, that any environment causing significant corrosion of an alloy will, by virtue of the notch effect of corroded surfaces, reduce the life of structures in that alloy under fatigue-loading conditions.

Further Tests

Continuation of tests in the humidity cabinet is at present in progress to evaluate the resistance of aluminum alloy Alcoa 61S-T4 to corrosion by the various chemicals. Tests are also being carried out on a number of multi-coat paint systems on Alclad, on protective coating systems for magnesium and with several other phosfattic fertilizers of potential importance for aerial topdressing.

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An Educational Lecture

Some Remarks on Stress Corrosion Testing*

By HUGH P. GODARD and J. J. HARWOOD

Introduction

THIS ARTICLE is intended to review briefly the testing of metals for susceptibility to stress corrosion and will deal with the purposes of testing, techniques employed and interpretation of results. It is by no means exhaustive and is written for the novice rather than the expert because most of what it contains has been published previously, although some experiences and opinions of the authors are included. Much of the material has been taken from the report of the American Society for Testing Materials, American Institute of Mining and Metallurgical Engineers, Symposium on Stress Corrosion Cracking of Metals[1] which was published in 1945. The subject is also treated at some length in a 1952 text by Champion on corrosion testing[2].

Recently, Harwood[3] reviewed information and theories on the influence of stress on corrosion. Stress corrosion may be defined generally as the acceleration of corrosion damage by the application of static stress. This might be termed, more appropriately, stress-accelerated corrosion. If acceleration of corrosion damage results in mechanical failure or rupture of the metal (the latter the most common experience) the term "stress-corrosion cracking" is used. Thus stress-corrosion implies a greater deterioration in the mechanical properties through the simultaneous action of static stress and exposure to corrosive environment than would occur by the separate but additive action of these agencies[4]. It often is difficult to differentiate between stress-corrosion cracking and the accelerating effects of stress in causing cracking with those alloys subject to intergranular corrosion in the absence of stress. True cases of stress-corrosion involve types of failures which do not occur in the absence of either stress or corrosive environment. It sometimes is assumed mistakenly that the mechanical failure of a specimen being corroded under stress is proof of susceptibility to stress corrosion. That this does not necessarily follow may be shown by a simple example. Suppose that the load carrying capacity of a given specimen being corroded in the absence of stress is within a month's exposure reduced from 1000 to 500 pounds. It is obvious then that the application of a 500 pound load would cause rupture within a month without any acceleration of corrosion by stress. It is, therefore, necessary when evaluating the susceptibility of metals and alloys to stress-corrosion, to expose unstressed as well as stressed samples to the corrosive environment, so that the time effect of stress can be determined.

The influence of stress on corrosion is quite specific, varying with both the metal and the environment. In general, the influence of stress on uniform surface corrosion rates is not of major practical significance. On the other hand stress may greatly accelerate localized corrosion by increasing the electrochemical activity of metal at local sites, by damaging protective surface films, by influencing polarization rates and by affecting the metallurgical characteristics of the metal system. The acceleration of localized corrosion by stress can be quite spectacular. An aluminum alloy containing 7 per cent magnesium, appropriately heat-treated to produce a certain type of micro-structure will crack within 30 minutes in a salt-peroxide solution, while an unstressed specimen of the same alloy

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Abstract

Some of the theories relating to the influence of stress in accelerating corrosion are reviewed briefly. A warning is given not to make assumptions on the resistance to stress corrosion of a material solely on the basis of a timed test because of the cumulative nature of the phenomenon. The merits and uses of several kinds of stress corrosion tests are explained and some of the factors to be considered in evaluating results enumerated. Influence of the environment, metal structure, specimen orientation, surface area and finish are considered. The several means of applying stress to specimens, the devices used to apply the stresses and some of the merits and demerits of various testing devices are considered. 33 references.

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will show negligible loss of tensile strength even after a week (10,000 minutes). A strip of stress-corrosion-sensitive sheet of the same alloy, bent to form a loop and immersed in a beaker of salt-peroxide solution, may rupture with sufficient violence to shatter the beaker.

Use of Stress Corrosion Tests

As noted by Sager, Brown and Mears[5] stress corrosion testing may be employed with several different ends in view:

1. The study of the mechanism of stress corrosion
2. The selection of the most suitable material for a given purpose
3. The determination of the limitations of a specific alloy
4. Guidance in alloy development work—effects of composition, heat treatment and production variables
5. A control test as a check on quality of product

Obviously no single procedure of testing will satisfy all five purposes and the extent and nature of testing will vary to some extent with the reason for making the tests. Most of the following comments will pertain to material selection and performance tests.

Influence of Stress

The principal factors involved in stress corrosion testing are stress, environment, internal structure and time. These will be discussed briefly with particular respect to test methods and interpretation of results. The stresses that will produce stress corrosion in service usually are residual stresses in the metal due to fabrication and assembly, or a combination of residual and operating stresses induced by service loads. General field experience has demonstrated that tensile stresses of considerable magnitude are necessary to produce stress corrosion—often in the order of the yield stress of the metal. In certain types of alloys however, even low stresses will induce rapid stress corrosion cracking, but, such situations are infrequent in service. Compressive stresses do not produce stress corrosion. In the presence of cyclic stresses under corrosive conditions mechanical failure may develop which is then known as "corrosion fatigue," a special subject beyond the scope of this discussion.

For full knowledge of the stress corrosion properties of a metal it is desirable to test specimens under a range of stresses and to plot loss of mechanical properties due to stress corrosion against applied stress. If cracking develops, this becomes a stress vs specimen life curve and the shape of the curve may become important in comparing stress corrosion susceptible alloys. A typical curve is shown in Figure 1.

The degree of applied stress may be plotted directly in psi, but frequently is expressed as a percentage of the yield stress because this figure frequently is used in design work.

The curve usually approaches the horizontal asymptotically at lower stresses and the estimated value of stress has been called the "stress corrosion cracking limit" by some and "threshold stress" by others, although neither term is widely used.

Wasserman[6] claims that plotting the stress-life curve on log log paper will give a straight line for many metals.

When it is necessary to restrict the testing to a single stress level it is common practice to adopt a certain percentage of the yield stress. In testing light alloys for aircraft the figure of 75 percent is widely used, especially in America, although there has been some discussion favoring a higher value, up to 90 percent of the yield strength.[7] In this connection it seems desirable to use the maximum service stress which will be applied to the metal over long periods.

When comparing different metals as to stress corrosion susceptibility it is debatable whether they should be compared at equal stresses or at equal percentages of their yield stresses. The latter is generally favored on the grounds that structures are designed on the basis of yield stress. In any alloy evaluation program, the choice of criteria may influence the relative order of stress-corrosion susceptibility of the alloys.[8] The importance of determining a complete stress-life curve in comparing alloys is illustrated in Figure 2.

If the shapes of the curves differ it is conceivable that at 75 percent of the yield stress alloy B may be superior to Alloy A while at 25 percent YS A may be superior to B. Curves of this type have been found by Bulow with a series of copper-zinc alloys in ammonia vapors.[8]

The effect of residual stresses induced by methods of fabrication or assembly must not be overlooked. These may be of greater magnitude than design stresses and hence their determination is of particular importance. They can often be estimated by appropriate methods.[9,10]

Influence of Environment

Stress corrosion tests may be made in natural environments such as the atmosphere or seawater but are more commonly carried out in the laboratory under artificial conditions. These may involve the use of synthetic atmospheres (e.g. controlled humidity, ammonia contents, salt spray, etc.) or be carried out by alternate or total immersion in chemical solutions. Testing conditions are specific to the alloy system and end use being studied.

Testing under conditions approaching those of service is most desirable. Laboratory tests which are frequently made severe to accelerate corrosion and reduce the time required may give misleading results and must be calibrated against service performance. If the test is made too severe it may lead to the rejection of alloys that have desirable properties and which would stand up in service. This is most important because especially severe conditions can be found for most metals that will stress corrode them. Therefore the development of susceptibility to stress corrosion in laboratory tests is not enough; it must be determined whether such susceptibility ever will be encountered in practice. It also should be noted that a laboratory stress corrosion test found suitable for one alloy system may not be applicable to another, even if the base metal is the same.

It is noteworthy that when stress corrosion cracking develops in service it nearly always occurs in an

environment, that produces only relatively mild corrosion. This suggests that, in stress corrosion testing, environments be chosen that do not cause excessive general corrosion.

Influence of Metal Structure

It is most important that the test specimens be representative of the production material in which one is interested. As the metallurgical structure is influenced by the manner of production, the best sample is one taken from a production lot. Obviously this is not possible always, especially in alloy development work but production practice must be simulated as far as possible. If the product of interest is in the form of sheet, extrusions, castings or forgings, then the sample must be of the same type. Conclusions drawn from one are not always applicable to another.

Consideration must be given also to the stability of the initial metallurgical structure. For example service at tropical temperatures may lead to ageing and changes in structure that will radically alter the stress corrosion resistance of the metal. In such a case testing the metal as produced is no guarantee of complete freedom from stress corrosion and artificial tropicalization or ageing treatments must be resorted to. These carry the uncertainty of correlation to service but are better than nothing. Treatments that have been used for this purpose are heating one day at 150 C, one day at 125 C, 1-3 days at 100 C or 4-28 days at 70 C. Work is underway to compare accelerated laboratory ageing with natural tropical exposure[14] for aluminum alloys.

Influence of Specimen Orientation

The direction of the applied stress may have a marked effect on the stress corrosion test results. This is due to orientation of the applied stress with respect to some features of the microstructure of the specimen such as shape and orientation of the grains and distribution of the grain boundary precipitate. In one series of tests, specimens cut along the longitudinal axis of an extrusion had a stress corrosion life exceeding two months while specimens stressed transversely to the extrusion direction failed in less than one day. That such differences may vary with the alloy composition was demonstrated when another alloy of the same base metal showed no such variation. On the other hand the observed variation found may have been due to difference in structure rather than alloy composition. Results obtained also may vary depending on where the specimens are cut from the material being tested. In another series of tests, specimens cut from the surface of an extrusion were found to be much more resistant than those cut from the interior. This was due to differences in structure between the surface layer and the interior.

It is necessary, therefore, to test for stress corrosion suspectibility in more than one direction of applied stress. The effect of specimen location also should be investigated. To determine the maximum degree of susceptibility to stress corrosion specimens should be stressed at right angles to the direction of working (i.e. rolling, extrusion).

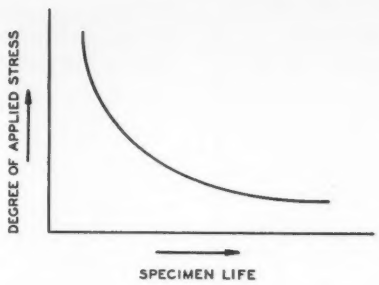


Figure 1—Typical stress-life curve.

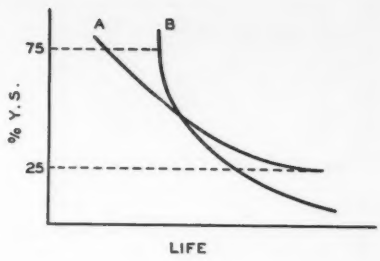


Figure 2—Comparison of stress-life curves.

Influence of Surface Area and Finish

In some cases at least, the surface area of the specimen also may have a bearing on the results obtained —shorter lives being found with large areas.[12,13] This has been shown related to the effect of increased cathode area rather than to any increased probability of location of a crack.[12] It also has been found that the scatter in results increases as the specimen area decreases.[13]

The means of preparation of the surface of the specimens also may affect the results.[13] A marked improvement in stress corrosion life results from cold working the surface (e.g. shot peening). This is due most probably to the setting up in the surface of compressive stresses.[14] These changes need occur only in a thin surface layer. It has been shown that specimens with a metallographic polish have a long life compared to similar specimens given a light chemical etch.

Influence of Time

One of the most difficult problems in interpreting results of stress corrosion tests is to decide when a material can be considered "safe" or free of stress corrosion susceptibility in service. The answer really can be decided only after correlation of the testing procedure with service performance, which requires extensive work and a long time.

It is customary to set a maximum testing time on the basis of experience and if the material survives this test it is considered safe. Champion[2,15] has dealt with this subject at some length. It is important to point out that stress corrosion does not occur at a constant rate. On the contrary there is increasing evidence that the major effect of superimposed stress in accelerating corrosion damage and cracking occurs mainly during the final stages of test, i.e. for long periods of time there is little evidence of the effect of stress and then failure may occur suddenly. Hence, any sort of "damage" test will not be a guarantee of absence of stress corrosion susceptibility because the test may merely have been of too short duration. The increase in rate of stress-corrosion damage with time is shown in Figure 3.

In the case of a new alloy of unknown merit, the

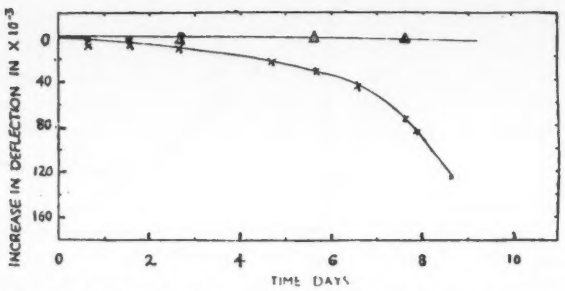


Figure 3—Acceleration of stress corrosion with time. (Figure courtesy Institute of Metals.)[13]

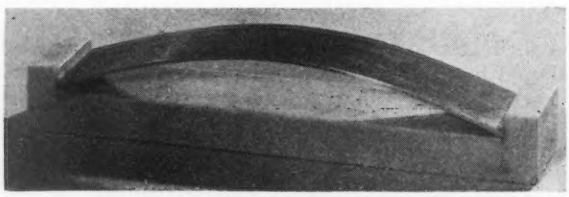
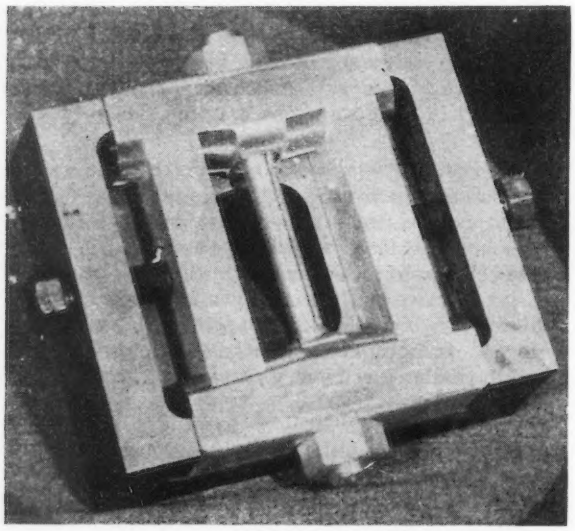
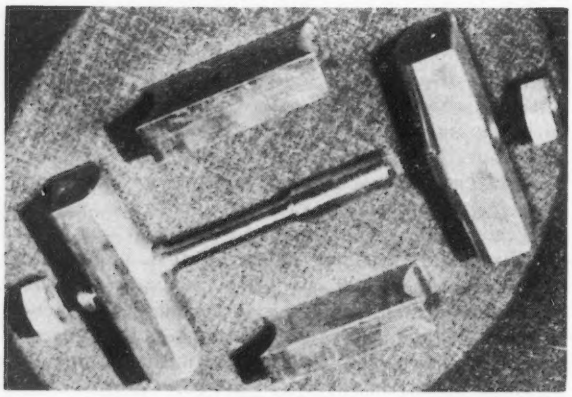


Figure 4—Constant strain bent strips.



a. Assembled



b. Exploded view

Figure 5—Constant strain wedge type jig.

safest means of evaluating its stress corrosion characteristics is to compare it with an alloy of the same base whose stress-corrosion properties are known.

Means of Application of Stress to Specimens

Stress can be applied externally by means of a loading apparatus or jig, or internally by inducing residual stress by forming or joining. Sometimes the specimens are formed or joined and externally stressed. The means of application of external stress are almost as numerous as investigators and many ingenious devices have been devised. Two main types have been evolved—those based on loading to constant strain (i.e. specimens stretched or bent to a fixed position) and those based on stressing by constant load (i.e. specimens stretched or bent by a constant load). In the latter type, as the cross section is reduced by corrosion or sub-surface penetration the actual stress increases and there is an acceleration of failure.

The former type, especially in the form of a strip deflected by loading as a simple beam has been the more widely used, mainly because it is simple and does not require cumbersome equipment. However, this procedure has been criticized because any creep of the specimen (more serious with some metals than others) relieves the stress and results in an unjustifiably long life. On the other hand, it has been argued that this is not a real disadvantage because once cracking begins it propagates rapidly and there is no time for such relaxation.[16] Another disadvantage of loaded beams is that the maximum stress is applied only to a limited area of the specimen on one side only. Calculation of this stress requires some assumptions and for some designs strain gauges must be used to prepare a deflection-stress calibration curve.

The constant load means of applying stress involves the fewest uncertainties. More bulky equipment is in general necessary although relatively inexpensive portable jigs of this type will be described later in this article.

The constant load type of test is preferable whenever possible, although with many alloy systems much useful information can be obtained with constant strain loading. It has been shown, at least for a number of aluminum alloys, that the two types of jigs give similar results for specimens with relatively short lives (e.g. 1-3 days), but it is believed that for alloys less susceptible to stress corrosion constant strain loading will give longer life due to relaxation of the stress by creep or plastic movement.

Often the variation in susceptibility to stress corrosion cracking produced by altering metal composition and heat treatment may be so large that relatively crude testing techniques can be employed to determine their general effects. Thus the means and accuracy of stressing are not too important in the early stages of an investigation in a new alloy development program. However, when the limits of composition and heat treatment are being located more closely, accurate stressing and constant load testing are to be preferred.

In general the reproducibility of stress corrosion

cracking results decreases as the life of the specimen increases, with the result that for longer life material the most accurate means of stressing is preferred.

Figure 6—Modified Loose and Barbion jig.

Specific Equipment

In view of the multiplicity of stressing equipment that has been used, no attempt will be made to cover all the various types reported. Many of these are described in the two reviews mentioned earlier.[1,2] Only a few jigs, illustrative of the types commonly employed, will be discussed including those which have been used by the authors.

1. *Constant Strain Bent Strips*

The surface stress can be calculated from Euler's approximate long column formula[11] which can be reduced to:

$$S = \frac{\pi^2 E}{L^2} \frac{hy}{2}$$

S = Extreme fiber stress (psi)
E = Young's Modulus (psi)
L = Length of specimen (in.)
h = thickness of specimen (in.)
y = deflection at center (in.)

It was found more accurate, however, to calibrate a fixed length holder against strip length using an electrical strain gauge.[19] Logan and Hessing[20] have suggested a stress calculation from the curvature near the center. The ends of the specimens and corners should be rounded to prevent restraint. In inserting the specimens care must be taken not to bend them too much so that they pass the elastic limit, especially at higher stresses.

Despite its disadvantages this method has been used extensively to locate clear-cut metallurgical trends in alloy development work.

2. *Constant Strain Wedge Type Jig*[21]

A number of these have been fabricated from aluminum alloys and used with success. They have the advantage that loads up to 5000 pounds can be applied with light portable equipment. The test solution can be placed in wax cups fitted around the specimens or the jig can be coated with paraffin saturated with gutta percha. This formulation, which is used in some English laboratories, has been found to be much superior to paraffin-beeswax and paraffin-rosin mixtures. A 5 percent solution of polyethylene in paraffin wax is still more durable. Sheet specimens can be tested by drilling a hole and using a pin to bear on the end pieces.

3. *Constant Load—Direct Loading*

Direct loading apparatus has been used[22] but it is bulky and has a high floor loading which limits its usefulness. Various investigators[23,24] have used lever devices, usually with a 10:1 ratio, to reduce the weights necessary but the equipment is still bulky and expensive. When applying the weights

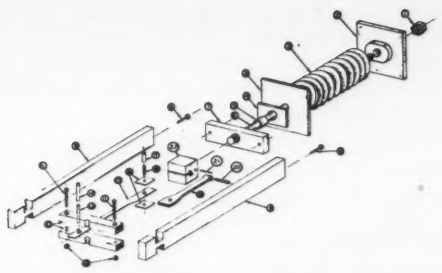


Figure 7—Exploded view of jig in Figure 6. 1, Stainless steel nut; 2, Aluminum spring centering bearing plate; 3, Zinc coated heavy steel spring; 4, Plastic strip; 5, Plastic sleeve; 6, Stainless steel rod; 7, Aluminum member; 8, Stainless steel bolts; 9, Aluminum members; 10, Aluminum member: 11, Stainless steel bolts; 12, Stainless steel nuts; 13, Stainless steel pin; 14, Nylon sleeve; 15, Test specimen; 16, Plastic washers; 17, Nylon sleeve; 18, Stainless steel pin; 19, Cadmium coated spring steel; 20, Stainless steel pin; 21, Stainless steel pin; 22, Aluminum block.

care must be taken to avoid impact and momentary overloading of the specimen which might exceed the elastic limit. In lever type equipment a feature not generally realized is that the bearing points of all knife edges should be on a line through the center of gravity of the beam, or the mechanical advantage of the beam will vary with its position.

4. *Constant Load—Spring Loaded Devices*

To avoid the use of heavy weights and cumbersome equipment various jigs have been employed in which the load is applied by means of a heavy spring with a linear stress-strain relation. Tracy and Thompson,[25] Loose and Barbian,[26] Perryman and Hadden[15] have described such units. One of the authors[27] has modified the Loose and Barbian jig as shown in Figure 6. An exploded view is shown in Figure 7.

The jig is coated with a baked-on polyvinyl plastisol[28] to prevent corrosion by the testing medium. This has been found permanent with results much superior to those obtained by all previous efforts at waxing and painting.

The jigs are fairly small and readily portable. They are placed directly in the corroding solution and a tank 20 x 38 inches will hold 35 units. The spring can be loaded to 1000 pounds. The nylon sleeves on the bearing pins prevent cutting through by the specimen.

If the specimens fail by tearing or stress cracking around the hole the local stress concentrations responsible can be eliminated by redesign of the specimen following the work of Lemaire[29] and Frocht and Hill.[30]

5. *Miscellaneous*

It is important to avoid dissimilar metal contacts in jig design, especially where the jig is immersed in an electrolyte. Galvanic corrosion currents will tend to protect the specimen if it is acting as a cathode or to accelerate stress corrosion if an anode.

With light alloys the latter must be especially watched because anodic corrosion under stress may be localized and rapid. Indeed the application of an anodic current in the order of 30-40 milliamperes per square inch has been used to accelerate the stress corrosion testing of some aluminum alloys.[31]

It sometimes is desirable to have breakage time indicators fitted to the jigs. This may be accomplished by having an electric clock which is cut off by a micro switch tripped by motion of the jig on failure. Periods longer than 12 hours can be timed by a spool device affixed to the clock.[32] Others have used a driven Veeder type counter which stops on failure.[25]

With alloys that are susceptible to lamellar corrosion, such as cold-worked Al-Mg alloys with higher magnesium content, the application of a bending moment reveals this tendency in a shorter time than axial loading, as might be expected.

Conclusion

By now, it is evident that stress corrosion testing is a somewhat complicated art. Dix[34] put this aptly:

> Accelerated corrosion tests, at best, are something of a hazard, and accelerated stress corrosion cracking tests are a hazard to the nth degree.

Nevertheless, stress corrosion testing is a necessary and important part of alloy development in many metal systems and has led to improvement in performance in a number of cases. An attempt has been made in this article to describe the effect of the various factors that influence the test, to present some pertinent information on testing equipment and on the interpretation of results. A modified inexpensive portable constant stress jig has been presented. It is hoped that these remarks will be found useful by newcomers in the field.

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NACE TECHNICAL COMMITTEE REPORTS

Publication 55-1

A Report of Technical Unit Committee T-2D on Standardization Of Procedures for Measuring Pipe Coating Conductance[1]

Tentative Standard Method for Measuring Electrical Conductance of Coating On Buried Pipe Lines

Abstract

A general method and an attenuation method for measuring the electrical conductance of buried or submerged pipe lines are proposed. Definitions, test conditions and set up, instruments, procedures, calculations and methods of reporting results are covered. Appendix includes pertinent formulae, suggested forms for making reports.

Introduction

THIS REPORT is the result of three years' work by members of Unit Committee T-2D of the National Association of Corrosion Engineers. While it represents the best answer available now the committee recognizes the probability that it will prove necessary to revise the method from time to time to make it conform to discoveries resulting from better techniques and equipment.

The unit committee is continuing its work evaluating methods for measuring electrical conductance of coatings. Persons with a contribution to this study are invited to participate in the committee's work.

Object

The object of this method is to establish a procedure for measuring the "leakage conductivity" of a buried or submerged pipe line. The use of leakage conductivity criteria in coating specifications and state code requirements, as well as in the evaluation of coating materials and efficiency of application techniques has made it necessary to recommend uniform methods for measuring this factor.

Definition

Leakage conductivity (C) of a sub-surface pipe line is the unit current per unit area that will pass when a unit potential exists between the pipe and remote earth. Leakage conductivity per unit length of pipe (k) is the quantity determined by measurement. This quantity (k) is influenced by:

1) the physical condition of the coating,
2) the surrounding soil, and
3) the contact conductance between the structure and soil.

These three components of leakage conductivity cannot be separated.

Test Conditions

Measurements shall be made on a section of electrically continuous pipe of uniform weight and with a coating of uniform materials and structure. The relations used to determine the leakage conductivity are based upon uniform current and voltage attenuation. In order that the current and voltage attenuation be uniform, the linear resistance of the pipe and the condition of the coating must be uniform.

Test Set-Up

Figure 1 is a sketch of the suggested test set-up. The section to be tested is divided into three sections L,L and 2L by test points A, B, C and D. At each test point the pipe-to-soil potential of the pipe line and the current flow in the line are determined.* Each test point contains test leads securely fastened to the pipe as shown in Figure 2.** (L, Figure 1) of the current measuring span Y (Figure 2) must be chosen to provide sufficient potential change consistent with the sensitivity of the measuring instrument. The length of the current span will depend upon the

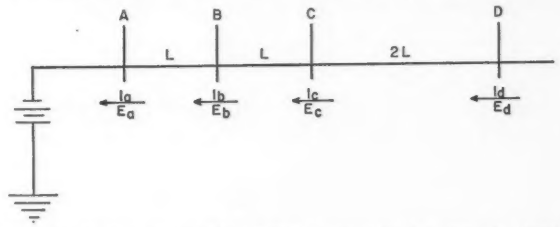

Figure 1—General test set-up. Details concerning use may be found under: Calculations—General Method.

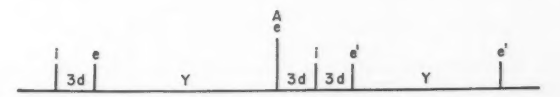

Figure 2—Details of test location. e — e, potential leads for determining current flow in pipe. i — i, current leads for calibrating the current section located at least three pipe diameters (3d) outside the potential span. e' — e', potential leads for determining end losses when calibrating current span. Y, current measuring span.

(1) William E Huddleston, Huddleston Engineering Co., Bartlesville, Okla., chairman.

* As described under "Instruments" hereafter.
** Spotting bars may be used in place of test leads but are not recommended.

instrument, the size and weight of the pipe and the current. As a guide, 100 feet is sufficient in most cases.

Instruments

Pipe potential measurements shall be made with a potentiometer or other zero-current meter read to three significant figures. Potential measurements shall be made with respect to a stable reference such as a saturated copper-copper sulfate electrode.

Potential measurements for determining pipe line current shall be made with a potentiometer or a millivoltmeter corrected for resistance of leads and contacts so that the measurements are made to at least three significant figures.

The source of drain current shall remain constant within one percent, or the necessary records of actual current during the test shall be kept so that measurements can be adjusted for the current drained at the time each measurement is made.

Test Procedure

Each current-measuring span shall be calibrated and corrected for end-current losses. An interrupted current shall be drained from the line, with the drain located at least 1000 feet from the test section. A convenient method of interrupting the current is an automatic switch with unequal intervals, the "on" interval the longer and the total cycle not to exceed one minute.

Three values of drain current shall be used in the ratio of approximately 1, 2 and 4. At each test point the pipe potential with reference to a remote electrode* and the current flow in the pipe shall be measured with the drain current "on" and with the current "off." At least three readings should be obtained for each measurement and the values averaged. The drain current shall not be changed until measurements are made with one value of drain current at all test points.

The length of the test section, L (see Figure 1), shall be selected so that the change in current at point B is not more than 90 percent of the change in current at A and the change in current at D is not less than 10 percent of the change at A.

Calculations

General Method

Leakage conductivity per unit length of pipe is calculated by the relation:

$$k_{ab} = \frac{2(I_a - I_b)}{L(E_a + E_b)} \times 10^{-6}$$

Where:

k_{ab}, k_{bc}, etc. = Leakage Conductivity in micromhos per linear foot for test sections AB, BC, etc.**
I_a, I_b, etc. = Change in current flow in amperes at test points A, B, etc.
E_a, E_b, etc. = Change in P/S in volts at test Points A, B, etc.
L = Length of test section in feet.

(The derivation of this formula is given in the Appendix.)

The linear conductivity k is converted to conductivity per unit area by the relation:

$$C = \frac{3.82k}{D}$$

Where:

C = Leakage conductivity in micromhos per square foot
k = Leakage conductivity in micromhos per linear foot
D = Outside diameter of pipe in inches

These relations will apply to most cases if the current at the test points is kept within the specified range and the pipe potential is taken with respect to a remote electrode. (If the leakage conductivity is 20 micromhos per square foot or less, potentials taken directly over the pipe may be considered remote.)

To check the data compare the measured resistance of the pipe obtained from calibrating the current spans with a calculated pipe resistance. The calculated linear resistance of the pipe (r) in microhms per foot is obtained by the relation:

$$r = \frac{2(E_a - E_b)}{L(I_a + I_b)} \times 10^{-6}$$

Attenuation Method

For most test procedures the method described will give sufficiently accurate results. Under certain conditions, however, it may be necessary or convenient to use test sections whose "electrical length" is too great for the application of the approximations used in the determination by the proposed method. Under these circumstances, coating leakage conductance may be computed by the use of the attenuation theory, using one or more of the equations given in the appendix.

A criterion for the determination of the "electrical length" of a section is the quantity αL. Figure 3 in the appendix shows graphically that if αL is not greater than 1.0, the error of the approximations will not exceed 8%.

Special Cases

1. Short Insulated Sections of Low Conductance
2. Inaccessible Locations Such as Water Crossings
3. Parallel Lines
4. Lines Where Marked Polarization Interferes with Measurement

The committee recognizes the special cases listed above but has not yet considered methods applicable to them.

Reporting Results

As stated in the definition, leakage conductivity is influenced by the physical conditions of the coating, the surrounding soil and the contact between the structure and soil. Moreover, the value of each component cannot be measured separately.

If leakage conductivity be used to evaluate coatings, information about the exposure conditions, including soil resistivity measurements should be reported as a part of the results.

The four-pin method[1] of measuring soil resistivity is recommended by the committee.

Suggested forms for reporting field data may be found in the appendix.

* A remote electrode is one so located that further separation of the electrode from the pipe being measured results in no significant change in voltage measurements.

** A conductivity of one micromho per foot is equivalent to a resistivity of one millions ohms in one foot.

Appendix

Derivation of Approximate Method

The relations for k and r are approximations and are the same as the $\Delta E - \Delta I$ method used by Rogers, et al.[2]

To derive the approximate equation for k: At any point,

$$-\frac{di}{dx} = ke$$

Where:

$\frac{di}{dx}$ = change in current per unit length of line, at any point
k = conductivity, mhos per unit length of line
e = change of potential of line, volts

Approximately, therefore:

$$\frac{\Delta I}{L} = ke$$

$$\Delta I = I_o - I_L$$

$$E = 1/2\,(E_o + E_L)$$

Where:

L = length of test section, feet
I_o, I_L = current change in line at ends of test section, amp
E_o, E_L = voltage change with respect to test current at ends of test section, volts

Hence:

$$k = \frac{\Delta I}{LE} = \frac{2(I_o - I_L)}{L(E_o + E_L)} \qquad (1$$

The relation for r is determined in a similar manner from

$$-\frac{de}{dx} = ri$$

Approximately,

$$\frac{\Delta I}{L} = rI$$

$$\Delta E = E_o - E_L$$

$$I = 1/2\,(I_o + I_L)$$

Hence:

$$r = \frac{\Delta E}{IL} = \frac{2(E_o - E_L)}{L(I_o + I_L)} \qquad (2$$

Derivation of Attenuation Method

For the general case (a "line segment"), solution of the foregoing differential equations for current and voltage gives:

$$E_L = E_o \cosh \alpha - \frac{L - I_o r}{\alpha} \sinh \alpha L \qquad (3$$

$$I_L = I_o \cosh \alpha - \frac{L - E_o \alpha}{r} \sinh \alpha L \qquad (4$$

Where:

$\alpha = \sqrt{rk}$

E_o, E_L, I_o, I_L, L are as previously defined[3]

The relations between current and voltage in (3 and (4 can be expressed as:

$$\frac{\alpha^2}{r^2} = \frac{k}{r}\,\frac{I_o^2 - I_L^2}{E_o^2 - E_L^2} \qquad (5$$

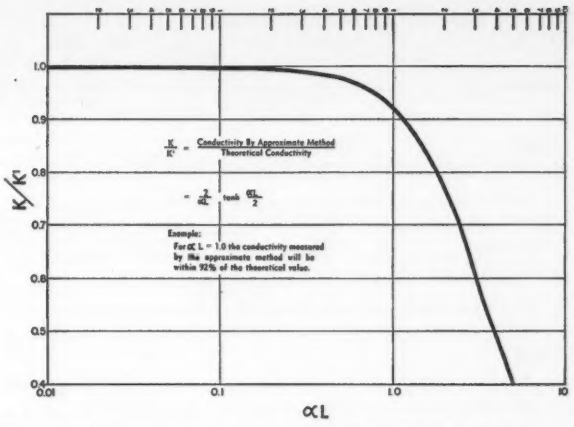

Figure 3—Measurement of coating conductivity. Theoretical accuracy of approximate method. $\left(\frac{K}{K'} = \text{as a function of } \propto L\right)$

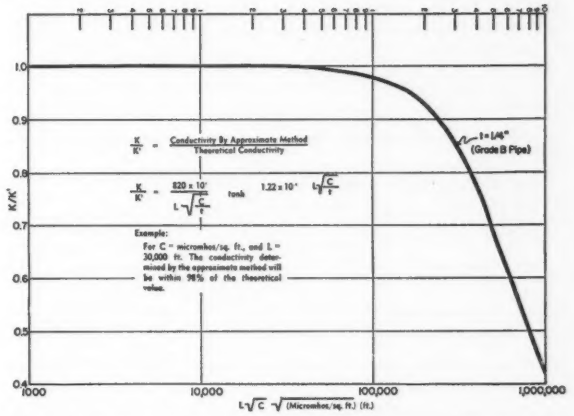

Figure 4—Measurement of pipe coating conductivity. Theoretical accuracy of approximate method. $\left(\frac{K}{K'} \text{ as a function of } L\sqrt{C}\right)$

Using k′ and r′ as the exact relations for the values of k and r,

$$k' = r'\,\frac{I_o^2 - I_L^2}{E_o^2 - E_L^2} \qquad (6$$

$$r' = k'\,\frac{E_o^2 - E_L^2}{I_o^2 - I_L^2} \qquad (7$$

The ratios of the approximations (1 and (2 to the exact relations (6 and (7 are for k and r:

$$\frac{k}{k'} = \frac{2}{r'L}\,\frac{(E_o - E_L)}{(I_o + I_L)} \qquad (8$$

$$\frac{r}{r'} = \frac{2}{k'L}\,\frac{(I_o - I_L)}{(E_o + E_L)} \qquad (9$$

The foregoing ratios are identical and reduce to:

$$\frac{k}{k'} = \frac{r}{r'} = \frac{1}{\frac{\alpha L}{2}} \tanh \alpha\,\frac{L}{2} \qquad (10$$

In Figure 3 is plotted the ratio k/k′ as a function of α L (attenuation constant times length of test section). In Figure 4 the ratio k/k′ is plotted as a function of $L\sqrt{C}$ (length of test section times square root

PIPE COATING RESISTANCE TESTS

Field Data Sheet 1
(All data refers specifically to test length)

Observers:_____ Test No._____
_____ Date_____

PIPELINE

Owner:_____ Name of Line:_____
Pipe: Size_____, Weight_____, Type & Grade_____
Joint Length:_____ Joints: Welded,_____, Screwed____, Welded Couplings____
Date Laid:_____ Times Reconditioned:_____ Date Last Reconditioning:_____
Remarks:_____
_____
Location of Test:_____

COATING

Materials & Structure:_____
Date Applied:_____ Yard or Field Applied:_____ Applied By:_____
How Inspected and Tested:_____
Remarks:_____
_____

CATHODIC PROTECTION

Date Applied:_____ Present Power Source:_____ Distance From Test Area:_____
Total Amps Drained:_____ Continuity Since Date Installed:_____
P/S Potential in Test Length: Min._____, Max._____ Volts.
Remarks:_____
_____

SOIL

Type:_____ Texture:_____ Usual Moisture_____
Depth of Cover:_____ Soil Moisture This date: At Top_____ At Pipe Depth_____
Remarks:_____
_____

PIPE COATING RESISTANCE TESTS

Field Data Sheet 2

Test No._____
Date_____

TEST LENGTH & SET-UP

Sketch:

Remarks: (Power source, anode, anode location, current control, "On-Off" frequency, etc.)

PIPE CALIBRATION

Test Point	Current, Amps. *	Line Drop, mv. *	Remarks*

* Do not neglect to take zero reading nor to indicate polarity.

REMARKS: (Method, meters, etc.)

PIPE COATING RESISTANCE TESTS

Field Data Sheet 3

Test No. _____
Date _____

TEST DATA

Test Point	Drain Current, Amperes		"Off" Readings		"On" Readings	
	"Off"	"On"	P/S Volts	Line Drop, mv. *	P/X Volts	Line Drop, mv. *

*Indicate Polarity: Current flowing toward test drain point is -
Current flowing away from test drain point is 6

of leakage conductivity). The purpose of Figure 4 is to establish the limits within which the general method can be used with acceptable accuracy. As an example, if results accurate to within 10 percent of the theoretical are desired, the product $L\sqrt{C}$ must be not over about 240,000.

Thus, a test section of moderately good coating with a conductivity of 10 micromhos per sq. ft. would give results accurate to within 10 percent if the test section were not over 76,000 ft. long. On the other hand, a relatively poor coating with a conductivity of 100 micromhos per sq ft could be evaluated to within 5 percent by the general method only if the test section were not over 16,000 feet long. Note that the foregoing examples are based upon the use of ¼-inch wall grade B pipe, for which Figure 4 is drawn. Similar curves can be drawn for pipe of other grades and wall thickness but would differ only slightly in the value obtained.

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NACE News

135 Hear O. B. Ellis Discuss Metal Coatings At Houston Meeting

The use of metallic coatings to prevent corrosion and a short history of metallic coatings was told by O. B. Ellis, Armco Steel Corp., to 135 Houston Section members and guests at the January 11 meeting held at Kelley's dining room, Houston.

Mr. Ellis, senior research engineer for his firm, supervises corrosion research activities. To show the antiquity of plating, he told his audience the Bible relates how Moses used gold and bronze as platings in building the tabernacle. Principally, Mr. Ellis dealt with zinc as a protective metallic coating; however, he also discussed coatings of aluminum, cadmium, tin, lead and stainless steel. On methods of application, he explained the hot dip, electroplating and metal spraying processes, spending most of his time on hot dip galvanizing with zinc. To illustrate the widespread use of zinc, he pointed out that enough zinc to coat every acre in Texas with 5 pounds is used in galvanizing each year in the United States.

Aluminum Aids Bending

In conventional hot dip galvanizing, steel-zinc alloy layers are formed which are brittle and limit the bending or drawing operations of galvanized steel, Mr. Ellis said. Small amounts of aluminum added to the zinc reduces greatly the brittleness of these alloy layers.

Confusion in terminology dealing with galvanizing was pointed out. Pipe ordered as one-inch pipe is not one-inch, he said. In the same manner, which a customer specifies 2 ounces of galvanizing per square foot, he received something less than this. The coating he receives is based on a total consumption in the galvanizing process of 2 ounces per square foot; however, some of the zinc is lost in the process. The following table illustrates this:

Standard or Ordered weight Oz. Sq. Ft.	Minimum Spot Weight* Oz. Sq. Ft.	Approximate minimum thickness (one side) in mills
2½	2.0	2
2	1.4	1½
1½	1.0	1
1¼	0.8	¾

*Total coating weight both sides.

To ensure uniformity of coating, Armco Steel Corp. uses a beta gamma continuous measuring device. As far as the purity of zinc being a factor in corrosion is concerned small amounts of alloying impurities appear to have no effect on corrosion resistance of the galvanizing, according to Mr. Ellis.

Forms of Corrosion

Several forms of corrosion on galvanized articles were discussed. "White rust" caused from condensation of moisture on sheets during storage was dealt with. A second type of corrosion, "buckshot" corrosion, occurs most frequently under water when there is a reversal of potential where zinc instead of being anodic becomes cathodic to steel and causes accelerated corrosion. He pointed out that the cause of reversal depends on temperature and composition of electrolyte which develops under favorable concentrations of certain ions.

In roofing applications, failure often occurs at lap joints where both top and bottom sheets corrode rapidly in the crevice formed by the lap. Preventive measures recommended by Mr. Ellis are a tight fit at the lap and painting the lap crevices.

Corrosion Rates Vary Widely

According to data accumualted by Mr. Ellis, atmospheric corrosion rates at a single location may vary widely during a year's time and may vary widely from year to year. Test exposure results covering any one period of time may vary widely from results obtained from tests conducted at a different time. Difference in location and the effect of the corrosion products on the rate of corrosion are significant factors. Length of time of exposure has a strong bearing on the rate of corrosion and the most economical thickness of coating to be used.

A location where corrosion continues at a steady rate until failure is quite different from where initial corrosion is great but tapers off rapidly to a slow corrosion rate, Mr. Ellis said. In the first case, the added thickness will prolong the life of the structure in proportion to thickness of the protective coating. In the second case, doubling the coating thickness will more than double service life. It also means that corrosion data procured during early stages of exposure can't be used to predict total life of the coating.

In addition to the technical talk, Section members heard Al Stegner, Tennessee Gas Transmission give a brief report on the work of the Houston Section as part of the Houston Engineer's Council over the past 5 years.

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The 1955 NACE Eleventh Annual Conference and Exhibition will be held at Chicago, March 7-11.

Payment of 1954 Membership Dues

In order to avoid interrupted mail and missed copies of CORROSION all NACE members who have not done so already are urged to remit their 1954 MEMBERSHIP DUES before March 31. Association by-laws require that the names of those whose dues are not received by March 31 be dropped from the membership mailing list.

NACE MEETINGS CALENDAR

Feb.

7 North Texas Section. Tentative speaker, Merrill Scheil, A. O. Smith Corp., Milwaukee.

8 Houston Section. Design of a Painting Program for New Construction by W. J. Eads, Products-Research-Service, Inc., Belle Chasse, La.

11 Philadelphia Section. Topic to be announced. Poor Richard Club, Philadelphia. Dinner 6:30 pm, meeting 8 pm.

15 Baltimore Section. Park Plaza Hotel. A talk on boiler corrosion embracing both water treatment and design considerations by Richard C. Ulmer, Combusion Engineering Co.

16 Genessee Valley, Joint meeting with Rochester Chapter, AIChE. Plastics for Corrosion Resistant Applications by Raymond B. Seymour, Atlas Mineral Products Co.

16 Greater Boston Section, Case History of Corrosion by F. L. Whitney, Jr., Monsanto Chemical Co. Hotel Beaconsfield, Brookline. Dinner 6:30 pm.

21 Lehigh Valley. Metallizing for Corrosion Resistance, Walter Meyer, St. Louis Metallizing Co. Keystone Trail Inn, same details as Jan. 17 meeting.

22 Montreal Section. Cathodic protection.

23 Niagara Frontier. Field of chemistry.

23 Ohio Valley Section, Joint meeting with AIEE. V. B. Pike, Bell Telephone Laboratories will speak.

24 Detroit Section. Joint meeting with The Electrochemical Society. Frank L. Whitney, Jr., Monsanto Chemical Co., St. Louis will speak on Mechanism of Corrosion Related to the Design of Equipment.

24 Niagara Frontier, Hamilton Niagara and Toronto Sections. Joint meeting with Electro-Chemical Society in Niagara Falls. J. F. Wilkes, Dearborn Chemical Co. to speak on Organic Inhibitors and the Role They Play in Control of Corrosion in Industry.

28 New Orleans-Baton Rouge Section. Internal Plastic Coatings for Tubing.

Mar.

3 Pittsburgh Section. J. G. Christ, Westinghouse Electric Co., will speak on Metallurgical Aspects of Corrosion in Atomic Power Applications.

7 North Texas Section. H. L. Bilhartz, Production Profits, Inc., chairman of South Central Region NACE will talk on secondary recovery.

29 Southwestern Ohio Section. Corrosion Resistance of Non-Ferrous Alloys by S. C. Lawson, Ampco Metal, Inc.

Libby Talks to Vancouver Section on Pipe Lines

H. T. Libby, British Columbia Electric Company, Vancouver spoke on external corrosion of underground pipelines at the December 9 meeting of the Vancouver Section. The 18 members and guests attending the meeting heard Mr. Libby, who has had wide experience in the underground corrosion of gas mains, discuss such factors as galvanic corrosion, differential aeration, bacterial corrosion, stray current and stress corrosion.

Mr. Libby also pointed out that cast iron has resisted corrosion remarkably well in the Vancouver area soils, far better than steel pipes laid in the same soils. Mr. Libby gave as an example of this the case of a cast iron main laid just before 1900 which was dug up recently and found to be virtually uncorroded.

Bureau of Reclamation's Coatings Use Discussed

Approximately 36 members and guests attended the December 17 meeting of the Rocky Mountain Section held in the Olin Hotel, Denver, Colorado. Paul Lewis of the Federal Bureau of Reclamation spoke on "Investigation of Protective Coatings by the Federal Bureau of Reclamation." Mr. Lewis discussed and presented slides to illustrate the tests of various pipe coating materials for internal and external pipe surface protection which have been made by the bureau.

During the business portion of the meeting, an unusually large number of requests for membership applications were received. Plans for sending a letter ballot to each section member were made following acceptance by the members present of the nominating committee's recommendations for section officers for 1955.

Corrosion of Structures Offshore Is Besse's Topic

C. P. Besse, Assistant Chief Engineer of the California Company, New Orleans, spoke on "Gulf of Mexico Corrosion" at the December 21 meeting of the Shreveport Section. Mr. Besse's talk covered such problems as designing, repairing, and maintaining fixed and mobile structures and protecting them from the ravages of corrosion in the Gulf of Mexico. During the business portion of the meeting it was announced to the 43 members and guests who attended that Fred D. Stull, Texas Gas Transmission Company of Owensboro, Kentucky will be guest speaker at the February 15 meeting. New officers for 1955 were also announced as follows: R. C. Jordan, United Gas Pipe Line, chairman; G. V. Jones, Arkansas Louisiana Gas Co., vice-chairman; M. A. Luby, Tretolite Company, secretary; J. D. Bland, Triangle Pipe Line Co., treasurer.

Plans are also being formed for a 2-day corrosion school to be sponsored by Shreveport Section in the early Spring. The exact dates have not been set.

Atmospheric Corrosion Problems Are Reviewed

H. R. Copson of the International Nickel Company, Inc., spoke on the subject of Behavior of Metals Subject to Atmospheric Corrosion at the December 28 meeting of the Metropolitan New York Section.

Approximately 75 members and guests heard Dr. Copson discuss the results of long term tests of both ferrous and nonferrous metals which had been subjected to industrial, marine and rural atmospheres. He also covered the effect of exposure conditions, length of exposure and types of specimens.

Following Dr. Copson's talk, the results of the election for 1955 were announced as follows: F. J. LeFebvre is chairman, F. E. Kulman is vice-chairman, and R. H. Lucke is secretary-treasurer.

SHORT COURSE CALENDAR

1955

Feb. 2-4—University of Toronto, Hart House Theater, Toronto.
Feb. 16-18—Tulsa Section, Sixth Annual Short Course, Mayo Hotel, Tulsa, Okla.
Mar. 1-4—University of Tennessee, Knoxville.
April 5-7 University of Oklahoma, Second Annual Corrosion Control Short Course, Norman, Okla.
April—University of British Columbia, Vancouver.
Fall—Washington University, St. Louis, Missouri.

Houston Section

A short course for pipeliners was held at the University of Houston by the Houston Section NACE, January 20 and 21.

Los Angeles Section

A five-day short course designed to orient newcomers in corrosion work on fundamentals of corrosion and corrosion control and jointly sponsored by the Western Regional Division NACE and the University of California in Los Angeles was scheduled to be held January 24-28.

The division's board of trustees scheduled a meeting January 26 at the Rodger Young Auditorium, Los Angeles, to approve the 1954 financial statement of the region and confirm instructions of representatives on the national nominating committee.

Tulsa Section

The 6th Annual Tulsa short course for pipeliners sponsored by Tulsa Section NACE is scheduled at the Mayo Hotel in Tulsa, February 16-18. It is to include discussions, lectures and actual field demonstrations on corrosion fundamentals, detection and prevention.

Authorities in the corrosion field will cover such topics as how to detect corrosion on pipe lines, methods for stopping corrosion with expendable anodes and rectifiers, instruments for corrosion control and how a pipeliner may help a corrosion engineer.

Further information concerning the course is availbale from Thomas M. Ragland, Box 996, Tulsa.

University of Oklahoma

At a regular meeting of the Central Oklahoma Section, held in the YWCA in Oklahoma City, Oklahoma it was announced that a corrosion short course school will be held at Oklahoma University, Norman, Oklahoma, April 5, 6, and 7.

Following the technical portion of the meeting at which E. J. Liggett, of Johns-Manville Sales Corporation, spoke on the subject of pipe line protection, it was reported that new officers for 1955 are: Clyve C. Allen, Anderson-Prichard Oil Company, Oklahoma City, chairman; Loyd Goodson, Oklahoma Natural Gas Company, Shawnee, vice-chairman; Clyde T. Norman, Johns-Manville Sales Corporation, Oklahoma City, secretary-treasurer.

East Tennessee Section Hears Norman Hackerman

Norman Hackerman of the University of Texas spoke on the "Theory of Acid Corrosion Inhibition" at the December 20 meeting of the East Tennessee Section in Oak Ridge, Tennesse.

Following Dr. Hackerman's talk, results of the recent election of officers for 1955 were announced as follows: James L. English, Oak Ridge National Laboratory, chairman; Solon Walker, East Tennessee Natural Gas Company, vice-chairman; Francois Kertesz, Oak Ridge National Laboratory, secretary-treasurer.

A progress report presented showed that since formal recognition of the section May 6 membership has grown to 22 of whom 10 live in Oak Ridge and eight in the Knoxville area.

Ulmer to be Speaker At Baltimore Feb. 15

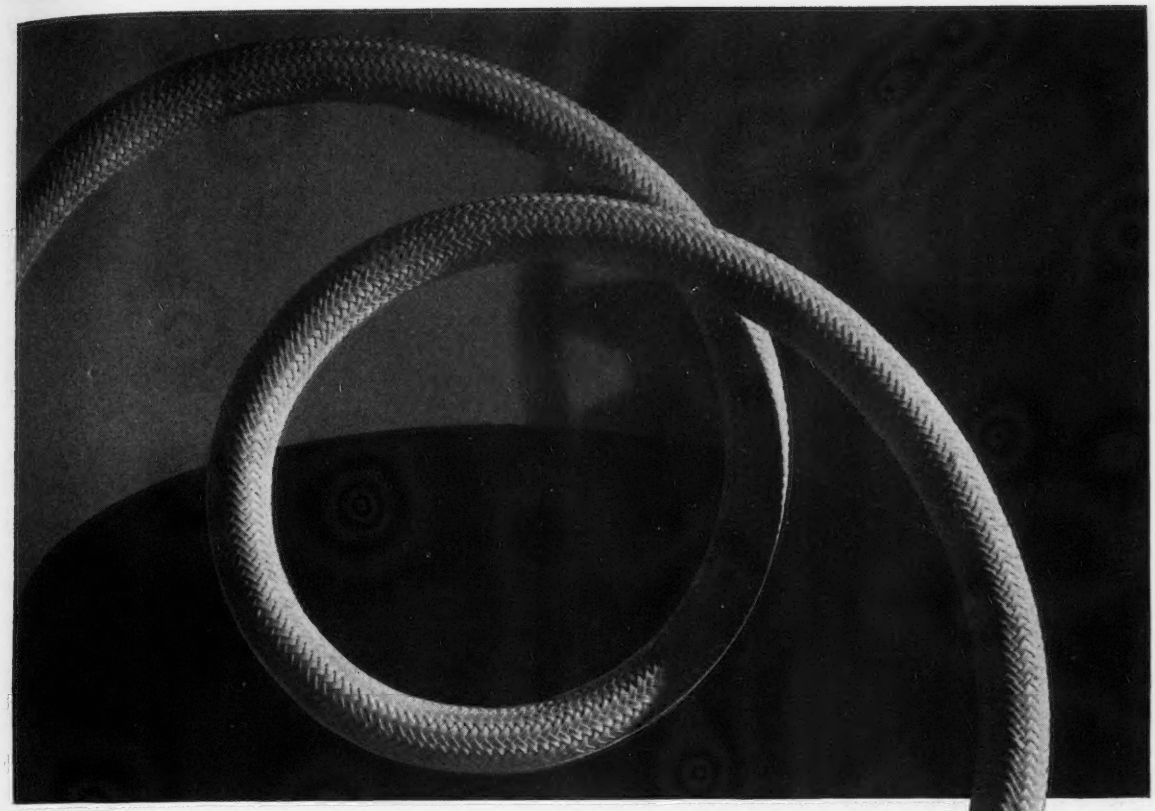
Baltimore Section NACE has scheduled its first 1955 meeting February 15 at the Park Plaza Hotel in Baltimore. Richard C. Ulmer, Combustion Engineering Co., is to speak on boiler corrosion embracing both water treatment and design consideration.

Northeast Region Officers

It has been announced that the following persons took over the duties of chairman, vice-chairman and secretary-treasurer of Northeast Region effective January 1 of this year: E. G. Brink, American Viscose Corporation, chairman; Frank Constanzo, Manufacturers Light and Heat Company, vice-chairman; J. E. Shields, secretary-treasurer.

South Central Officers

Effective January 1, 1955 J. E. Loeffler, Houston; J. W. Nee, Corpus Christi; E. C. Greco, Shreveport, La. and J. P. Barrett, Tulsa, Okla., took the offices of chairman, vice-chairman, secretary-treasurer and assistant secretary-treasurer of South Central Region.



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handles working pressures up to 250-300 psi

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This outer braid reinforcement still permits visual observation of flow; the reinforced tubing is still fully flexible.

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Tygon Tubing, outer braid reinforced, is stocked in five standard bore sizes: 1/4", 3/8", 1/2", 3/4" and 1". Other sizes on making order. Unbraided Tygon Tubing is stocked in 58 bore sizes from 1/16" to 2".

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- **FLEXIBLE**
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and still retains

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For ninety years The United States Stoneware Company has been a major producer and fabricator of materials designed to withstand corrosive attack. Such well-known industrial trade names as TYGON, DURALON, PLASTILE, DENSTONE, INTALOX, REPUBLIC LEAD, TYLOX, TYGOWELD, COLONIAL RUBBER identify other materials and products manufactured by us or our affiliated companies.

POSITIONS WANTED and AVAILABLE

- Active and Junior NACE members may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.
- Firms seeking employees, regardless of NACE membership, may run an advertisement of the same specifications indefinitely.
- Advertisements to other specifications will be charged for at standard rates.

Positions Available

Corrosion Engineers. Positions available for graduate electrical engineers or equal. Previous field and design experience in corrosion mitigation systems required. Extensive travel involved. Salary open. The Hinchman Corp., Engineers, Francis Palms Bldg., Detroit 1, Mich.

Sales Representatives for DEL Protective Coatings. Protected territories available to qualified individuals or companies. No objection to carrying non-competitive lines. Write David E. Long Corp., 220 East 42nd St., New York 17, N. Y.

Corrosion Engineer—Graduate engineer with field and design experience in cathodic protection systems. Extensive travel. Salary open. Harco Corp, P. O. Box 7026, Cleveland 28, Ohio.

Manager—To manage reorganized department for sale of corrosion-proof materials. Good understanding of corrosion-proof materials or construction and sales experience in this field necessary. Location Cleveland. Write full details. CORROSION, Box 54-22.

Positions Available

Opportunity in multi-plant chemical company for person experienced in evaluation and solution of corrosion problems, familiar with fabrication and use of metallic and non-metallic materials. Fundamental studies, plant and customer trouble shooting, contact with fabricators and suppliers included. Location in metropolitan New York area. CORROSION, Box 55-4.

Junior Corrosion Engineer—Recent graduate for work in marine corrosion at Harbor Island and Kure Beach Corrosion Test Stations near Wilmington, N. C. Write T. P. May, International Nickel Co., Inc., 67 Wall Street, New York City.

Agents and Distributors to represent nationally known company manufacturing a complete line of abrasion- and corrosion-resistant protective coatings, sealing compounds and industrial adhesives. May easily be carried with other lines; protected territories. Magic Chemical Company, Brockton, Mass.

CHEMICAL or METALLURGICAL ENGINEER

Leading chemical company has key position open in large Eastern plant. Should have a few years' experience with chemical plant corrosion problems.

Responsibilities will involve corrosion investigation for new and existing processes and development work in applying new materials of construction and corrosion prevention methods. Well equipped metallurgical corrosion laboratory and trained technicians available. CORROSION, Box 55-3.

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***with* DU PONT**
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A unique career opportunity is now available in our Engineering Department to a graduate metallurgist or metallurgical engineer (advanced degree desirable) whose education included a minor in physical chemistry, engineering materials, or corrosion engineering. Experience should include evaluation, selection, specification, and use of materials of construction, both metallic and non-metallic, for process equipment. This should include both corrosion properties and fabrication procedures, including forming, welding, stress relieving, heat treating, and inspection. The successful applicant will provide consulting service to operating plants and to the Engineering Department on problems in the above engineering materials fields. Problems in plant operations will include evaluation of performance of materials in process equipment to prevent product contamination and to reduce maintenance to a minimum. This provides an extremely wide field of application in a great variety of processes.

Please send complete resume, including details of education and experience, to:

Mr. J. C. Costello, Jr.
Engineering Dept., Personnel Section
E. I. du Pont de Nemours & Co., Inc.
Wilmington 98 Delaware

Kirk H. Logan, Speller Award Honoree, Dies

Kirk H. Logan, research engineer for The Cast Iron Pipe Research Association, Washington, D. C., and recipient of the National Association of Corrosion Engineers 1951 Speller Award, died recently of a heart attack. He had devoted more than 33 years to corrosion work.

Mr. Logan was born on a Rice County, Kasnas farm January 25, 1879. After graduating from Kansas University in 1902 he taught at Friends University, a small Quaker college in Wichita, Kansas and during the next two years taught physics at Bradley Institute, Peoria, Ill. He then became a student engineer at the Lynn Works of General Electric Co. and the following year traffic engineer for the New York Telephone Co.

For the next four years Mr. Logan taught physics at Kansas A. & M. College during which time and in preceding periods he took graduate work at Brooklyn Polytechnic Institute, The University of Chicago and other schools, receiving an MS degree from KSAC in 1913.

In 1911 he joined the scientific staff of the National Bureau of Standards where he worked on electrolysis problems until 1922 when he organized and directed the bureau's underground corrosion investigations until 1944. During this period he wrote numerous papers on corrosion, including the final report of The American Petroleum Institute's study on pipe coatings. His last work for the bureau was preparation of its Circular C 45 "Soil Corrosion," which summarizes the bureau's underground corrosion work.

As research engineer for The Cast Iron Pipe Research Assn., Mr. Logan experimented with methods for preventing corrosion.

He was a Fellow and Life Member of the American Institute of Electrical Engineers, a member of the National Association of Corrosion Engineers since its inception, a member of the Electrochemical Society and several trade organizations. Mr. Logan was a member of the Unitarian church.

Bowman Is Honored

John R. Bowman, director of research at the Mellon Institute for Industrial Research, was named recipient of the 1954 Professional Progress Award in Chemical Engineering sponsored by the Celanese Corporation of America and administered by AIChE.

Positions Wanted

B Ch E 1957, night student, age 23, family. Two years' experience corrosion protection, surface coating. Employed service engineer large industrial cleaner manufacturer. Want corrosion work in greater N. Y. area. CORROSION, Box 55-1.

This Corrosion Engineer has made profits for employers in technical sales, plant and general management. Knows selection, estimating, plant practices and sales of coatings, linings, rigid sheet and metallizing. Graduate engineer. Seeks application shop challenge. CORROSION, Box 55-5.

Wilkes to Speak at Four-Group Meeting

WILKES

Niagara Frontier, Hamilton Niagara and Toronto Sections NACE are scheduled to hold a joint meeting with The Electrochemical Society at the Red Coach Inn in Niagara Falls February 24. J. F. Wilkes, director of research and development, Dearborn Chemical Co., Chicago is to speak on Organic Inhibitors and the Role They Play in the Control of Corrosion in industry.

Stauffacher Retires From California Edison

E. R. Stauffacher, chairman of the Rules Subcommittee, Publications Committee, NACE, has retired after 44 years of continuous service with Southern California Edison Co., Los Angeles.

Mr. Stauffacher graduated from the Alabama Polytechnic Institute at Auburn in 1910 with a BS in Electrical Engineering. He was awarded a professional EE degree in 1920.

In 1910 he joined the Southern California Edison Co., and was concerned with overhead and underground distribution systems, power engineering involving use of electricity on consumers' premises and protection engineering covering application of protective relays, lightening arresters and grounding systems to generating plants and substations.

In 1927, he served as exchange engineer at the General Electric Co., in Schenectady, N. Y., and during World War II spent a short period at the California Institute of Technology on studies of wave action in Long Beach Harbor.

Prior to his retirement Mr. Stauffacher dealt with problems on corrosion control and application of protective coatings throughout the Southern California Edison Company system.

He is a member of the American Institute of Electrical Engineers, American Society for Metals, American Water Works Assn., American Geophysical Society and Pacific Coast Electrical Assn. He lives at 531 Fischer, Glendale, California.

AIChE Officers Named

Barnett F. Dodge, professor and head of the Department of Chemical Engineering, Yale University, has been elected president of the American Institute of Chemical Engineers. Arthur K. Doolittle, assistant director of research, Carbon and Carbide Chemicals Co., South Charleston, W. Va., is vice president and George Granger Brown, dean of engineering, University of Michigan, was re-elected treasurer.

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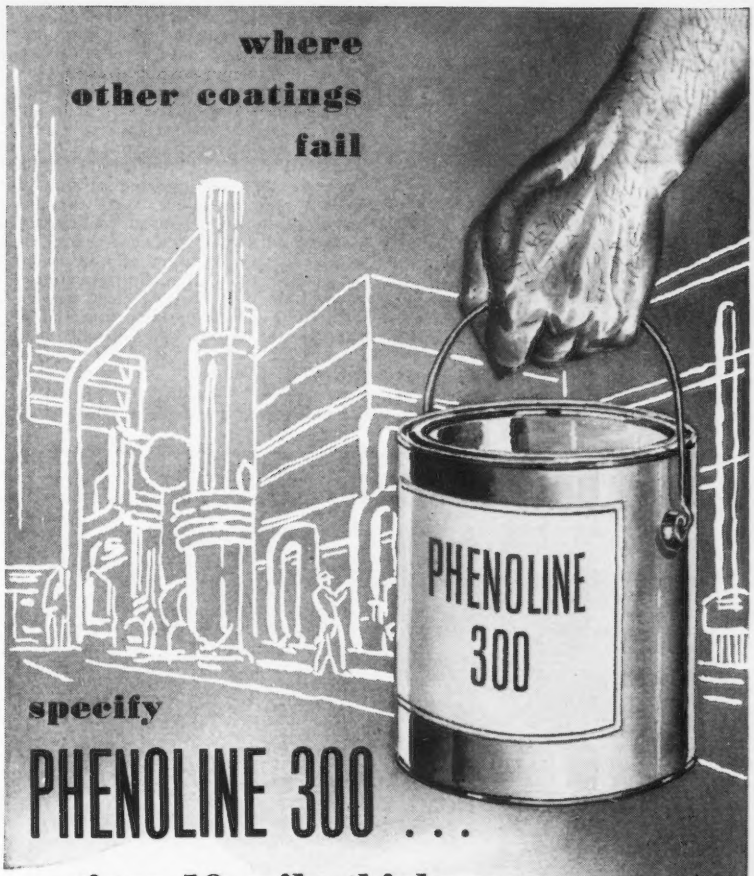
In 9 years CORROSION's Technical Section pages numbered more than 3000.

Lists of literature available from NACE may be had on request.



gives 10 mils thickness per coat

for heavy duty protection of steel in severe corrosive environments

Heavy duty protection is required for areas in chemical processing plants and other industries where *severe* corrosive conditions are present (high fume concentration, heavy splash and spillage). Vinyls and other relatively thin coatings, which do not give heavy duty protection, fail in these environments.

But Phenoline 300 (a modified thermosetting phenolic) gives you this vital protection and saves you money, too. Here's why:

- 10 mils (.010") thickness per coat. This means fewer coats required, lower application cost.
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Turbine Blade Heat Is Indicated by Instrument

An instrumentation system for remote indication of gas turbine blade temperatures has been designed for Navy Bureau of Ships by the National Bureau of Standards. System includes special high-temperature resistence thermometers, an inductive commutator and electronic circuitry.

Essentially the inductive commutator consists of pairs of input and output coils on rotating shaft with one stationary set of energizing and information-receiving coils mounted on turbine frame. Rotation of shaft brings each coil pair into and out of coupling with stationary coils. Each channel or set of rotating coils is sampled periodically with rotation thus signal information is sequential in nature. Since commutator is non-contacting there is no wear problem and vibration amplitudes and presence of oil and water vapor have virtually no effect upon transfer properties. Shaft may be run in either direction without modification of unit. Electrical circuit of inductive coupling is simple; one stationary coil is exited with current at low radio frequency and the other serves as source of output voltage. On rotating structure coil pairs are electrically connected together and shunted by variable-resistance thermometer element. One pair couples electromagnetically with exciting stationary coil and other with output coil. Result is the amount of energy transferred through device is governed by resistance of thermometer element when its particular rotating coil pair is coupled to stationary coils. The magnitude of output is independent of speed of rotation.

In order to remove dependence of magnitude of output voltage on strength of excitation of input coil one of the channels is used for calibration and a fixed known resistance is substituted for one of temperature sensitive elements. Thus ratio of output of any of signal channels to that of calibration channel is true measure of resistance of sensing element.

Five rotating coil pairs provide four-channel measurement system with the fifth reserved for calibration. Five synchronizing coils surround commutator coils and allow selection of any one channel for observation. Selection is accomplished by gating on source of r-f excitation when chosen rotating pair comes between fixed coils. Gating is achieved by mounting short piece of high-permeability material around outside of rotating disk so that it is centered under synchronizing coils whenever signal coil pair is at maximum coupling. Channel selection is independent of speed and direction of rotation.

Electronic circuit portion of system provides necessary radio-frequency excitation and output interpretation for inductive commutator. Essential elements include synchronizing pulse generator, gated excitation oscillator, output signal amplifier and peak voltage detector. Electronic unit is connected to commutator through 50-foot cables for remote location away from engine testing pit.

CONTROLLING CORROSION

Air View of Port Newark Southside Wharf

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This is another application of our Engineering Division "know-how" that since 1935 has been successfully controlling corrosion to reduce maintenance costs in buried and submerged steel structures of many types. Because E.R.P. engineers are corrosion control specialists, you can depend on them for the most economical solution to your corrosion control problem.

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Corrosion Engineers in Israel Are Organized

A group of engineers in Israel has organized for cooperative solution of corrosion problems, according to D. Spector, a member of the National Association of Corrosion Engineers living in Tel Aviv. Mr. Spector, who attended the NACE Conference in Kansas City in 1954 said the success and method of organization of NACE had inspired him to proceed with organization of a group in his homeland.

Mr. Spector also will be responsible for the Corrosion Section of the Engineers' and Architects' Journal which is published in Hebrew. English abstracts of technical material will be published.

Six Short Courses Are Participated in by NACE

Six short courses on corrosion in which NACE participated were held during 1954. They were:

Berkeley Marine Corrosion Conference—Feb. 8-9.

Washington State University—Feb. 1-5.

Tulsa Pipe Liners Short Course—Feb. 17-18.

Shreveport Pipe Liners Short Course—Feb. 18-19.

Niagara Frontier Section—University of Buffalo Underground Corrosion Symposium—Oct. 27-28.

Los Angeles Section—UCLA—Nov. 15-17.

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NACE's Western Region plans to hold two short courses each year. Attendance is not restricted to members of NACE.

Technical Committee News

95% of Valve Repair Costs Are Laid to Corrosion

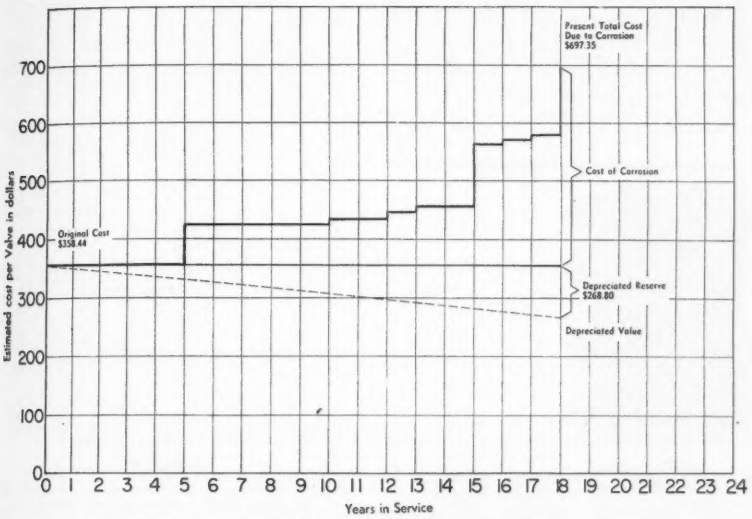

Figure 1 — Average cost per valve installed vs years in service for thirty-two 20-inch gate valves in old section of Orinda Filter Plant.

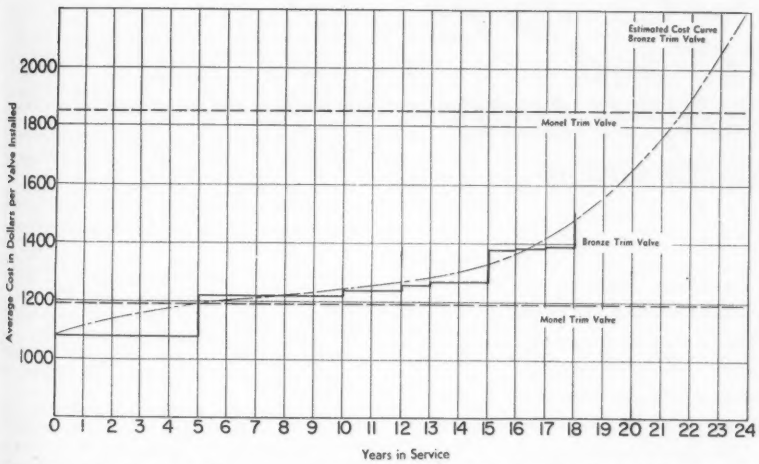
Estimated Cost Curve Bronze Trim Valve
Monel Trim Valve
Bronze Trim Valve
Monel Trim Valve
Average Cost in Dollars per Valve Installed
Years in Service

Figure 2 — Estimated cost per valve vs years in service for 20-inch gate valve with bronze trim at current prices.

Sulfide Stress Corrosion Cracking Meeting Set

Unit Committee T-1G on Sulfide Stress Corrosion Cracking will meet February 23 and 24 to discuss the current sulfide stress corrosion research project being supervised by the committee at Yale University. The meeting will be held at the Yale University Hammond Metallurgical Laboratory in New Haven, Connecticut.

First day of the meeting will be taken up by discussion on the progress of the research project by Professor W. D. Robertson of Yale. The second day will be an executive session to decide future action on the project.

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Discussions and comments on material in CORROSION'S Technical Section are welcomed for review prior to publication.

Galvanic Currents Between Bronze, Cast Iron Noted

By WILLIAM G. ELLIS*

At a meeting of Technical Unit Committee T-4F on Materials Selection for Corrosion Mitigation in the Utility Industry held in Los Angeles on November 18, a report was given to the committee on the cost of repairing corroded gate valves in a municipal water filter plant. The report was prepared for presentation to the committee by William J. Ellis, East Bay Municipal Utility District, Oakland. It was received by the committee and the committees' grateful appreciation was expressed to Mr. Ellis and to the East Bay Municipal Utility District for its cooperation and contribution to the group's efforts.

Introduction

THIS investigation was requested as a result of frequent repairs of 20-inch gate valves in the old section of the Orinda Filter Plant.

A history of each of the 32 valves investigated, the repair costs since January 1951, the cause of corrosion and recommendations are included in the report.

History

In 1936, the district purchased thirty-two 20-inch flanged, double disc, square bottom gate valves with outside screw and yoke for $11,470.04, including thirty-two 12-inch hydraulic cylinders. The valves were installed that same year in the pipe gallery of the Orinda Filter Plant, which then consisted of only eight filters. Each filter has a left and right filter valve, a washwater valve and an effluent valve. All valves stay open during filtering operations except the washwater valve. Filters are washed approximately every 96 hours, when the washwater valves are opened and the effluent and one filter valve is closed.

Results

Results of the investigation are shown in tabular form in Tables 1 through 4.

Repair dates shown in Table 1 were obtained from the supervisor of the Orinda Filter Plant, who checked through the filter plant operators' daily log books for notations on valve repairs. Daily log books have been kept only since 1941. So information prior to this date is not available. Only repairs indicated as being necessitated directly by corrosion have been shown in Table 1.

*East Bay Municipal Utility District, Oakland, Cal.

(Continued on Page 70)

95% of Valve Repair—

(Continued From Page 69)

A list of repair orders and costs which apply to the valves being investigated are shown in Table 2. These data were obtained from the accounting department.

Information in Tables 1 and 2 was combined to determine the cost of repairs and the number of valves repaired each year. This is shown in Table 3. Cost of repairs for the years prior to 1951 were estimated from the average cost per valve repaired during 1951 ($182.71). Records show an average increase in labor charges of 80 percent between 1941 and 1951, which reduced the average cost of $182.71 to $101.40 for 1941. A straight line increase in labor costs was assumed for the remaining repair years and the average cost per valve repaired in 1941 was increased 50, 70 and 80 percent for 1946, 1948 and 1949 respectively. Since the repair costs shown in Table 2 are 90 percent labor and 10 percent material, and since cost of materials has increased up to 300 percent, the assumptions made in Table 3 are considered conservative.

Table 3-A contains the same information included in Table 3 but is corrected for current prices. It was assumed there was no increase in labor cost between 1951 and 1954. The average cost per valve repaired for this period was $232.13. This figure was used to determine the cost of repairs for the period 1941 through 1949 giving an estimate of costs had the valves been repaired at current prices.

Data in Table 4 were determined by using an average depreciation of $4.98 per valve per year since 1936. The present total cost was determined by adding the average repair cost per valve installed to the original cost. This information is plotted in graphic form in Figure 1.

Costs per valve installed contained in Table 3-A were added to the current price of a 20-inch valve and plotted in Figure 2. The current price of two types of equivalent Monel trimmed valves is also shown in Figure 2 for comparison.

TABLE 1
Repair History of 20-Inch Gate Valves at Orinda Filter Plant

No.	Valve	YEAR REPAIRED 41	46	48	49	51	52	53	54
1	L-Filter	x				x			
	R-Filter	x				x			
	Washwater	x	x			x	x		
	Effluent	x							x
									x
2	L-F.	x		x		x			
	R-F.	x		x		x			
	WW.	x		x		x			
	Eff.	x							x
									x
3	L-F.					x			
	R-F.		x			x			
	WW.	x				x			
	Eff.	x							x
4	L-F.					x			
	R-F.					x			
	WW.					x			
	Eff.	x							x
5	L-F.	x				x			
	R-F.	x				x			
	WW.	x							x
	Eff.	x							x
6	L-F.					x			
	R-F.					x			
	WW.				x				
	Eff.	x							x
7	L-F.					x			
	R-F.					x			
	WW.							x	
	Eff.	x							x
8	L-F.	x				x			
	R-F.					x			
	WW.	x						x	
	Eff.	x							x

TABLE 2
Repair Orders on 20-Inch Gate Valves at Orinda Filter Plant April, 1954-October, 1954

DESCRIPTION	Amount
Repair Gate Valve 7-L Filter 20"	$ 488.17
Repair 5-R Filter Valve	133.70
Repair 6-R and 6-L Filter Valves	132.21
Repair Filter Valves	227.17
Repair 28—20-inch and 8—8-inch	2,672.85
Repair No. 1 Washwater Valve	89.38
Repair Valves	223.00
Perform Work on Valves as Required	3,280.60
Repair Washwater Gate Valve on No. 5 Filter	295.60
Recent Repairs Performed on this Function No.—Estimated	350.00
Total Repair Costs	$ 7,892.68
Original Purchase Price, 1936	$11,470.04

Discussion of Results

Table 1 indicates the frequency of repairs due to corrosion on the thirty-two 20-inch gate valves being investigated. The only source of information for these data was the filter plant operators' daily log. This record checks reasonably close with the repair orders listed in Table 2, but the possibility remains that repairs may have been performed on these valves prior to 1951 and not recorded in the daily log. If this is the case, Table 2 contains the only com-

(Continued on Page 71)

For a period of 12 years the Nelson Electric Manufacturing Company has been furnishing Phenolic Insulating Materials for pipe nipples and the insulation of pipeline flanges. We introduced the use of thin-wall tubing sleeves for insulating the studs in standard flanges, without requiring re-drilling of the flange and providing smaller studs. We now offer flange insulation, packaged for immediate shipment on the more common sizes.

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95% of Valve Repair–

(Continued From Page 70)

pletely accurate information and the remaining tables and curves show only the minimum cost picture.

Referring to Table 2, the total cost of repairs resulting from corrosion between 1951 and 1954 amounts to $7892.68. Original purchase price of thirty-two 20-inch bronze trimmed gate valves was $11,470.04. In 3¾ years of operation, the cost of corrosion amounts to 68.8 percent of the original investment.

Purchase price of each valve was $358.44. Estimated total cost of repairs per valve installed determined from Table 3 is $338.91. In 18 years of service the cost of corrosion amounts to 94.5 percent of the original investment.

Referring to Table 4 and Figure 1, the cost of corrosion per valve at any time is the difference between the present total cost curve and the original cost. Depreciation reserve is the difference between the original cost ($358.44), and the depreciated value ($268.80), which is $89.64 at the end of eighteen years. The difference between the estimated present total cost ($697.35) and the original cost is the cost of corrosion per valve installed, which is $338.91 for eighteen years. Therefore, during eight-

(Continued on Page 72)

TABLE 3

Repair Cost Due to Corrosion, Per 20-Inch Valve Installed at Orinda Filter Plant for 18 Years' Service

YEAR	Cost of Repairs	Valves Repaired	Cost per Valve Repaired	Cost per Valve Installed	Years in Service
1954	3926.20	11	356.93	122.69	18
1953	223.00	2	111.50	6.97	17
1952	89.38	1	89.38	2.79	16
1951	3654.10	20	182.71	114.19	15
1949*	166.29	1	166.29	5.20	13
1948	474.54	3	158.18	14.83	12
1946	283.92	2	141.96	8.87	10
1941	2028.00	20	101.40	63.37	5

* Data for the years prior to 1951 was estimated from the average cost per valve repaired between 1951 and 1954, allowing for increase in labor costs.

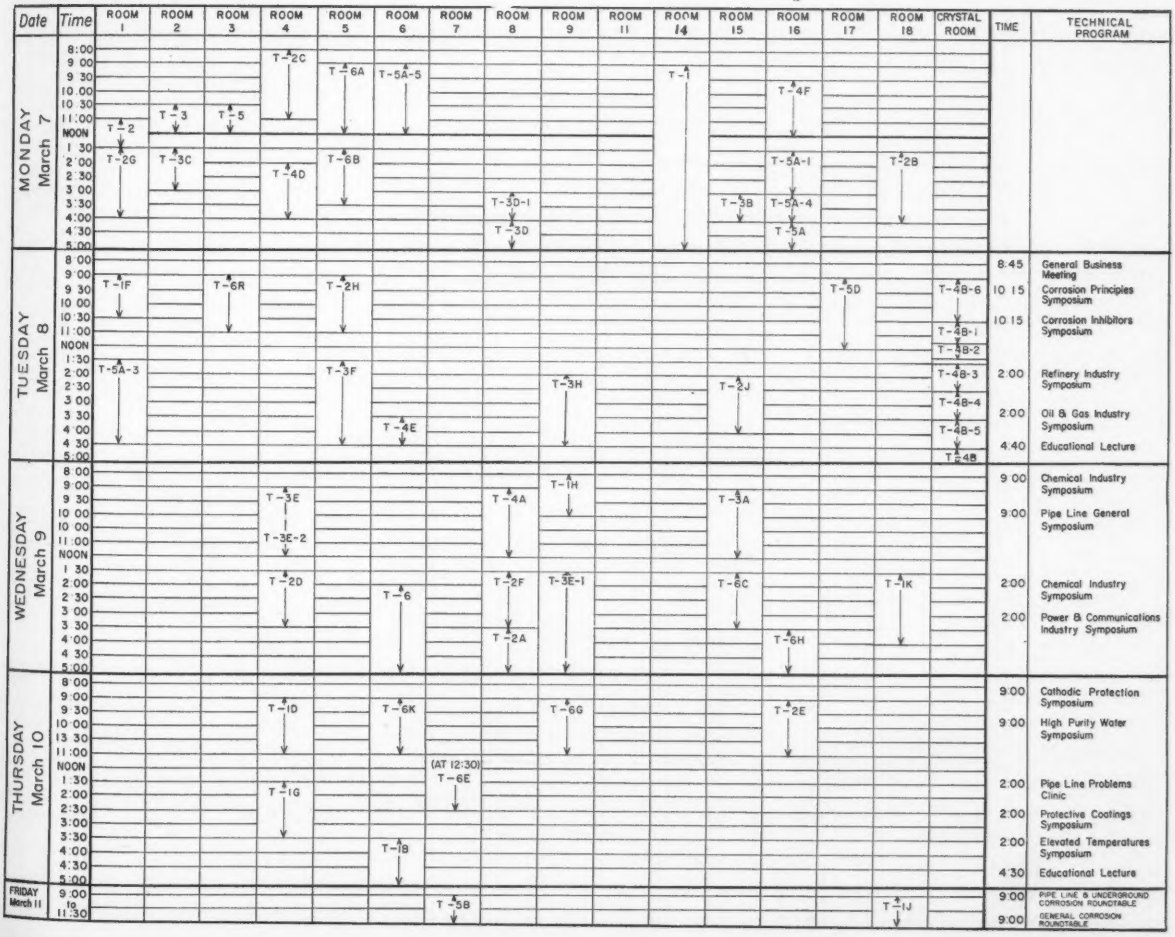
TABLE 3-A

Repair Costs, at Current Prices, Due to Corrosion Per 20-Inch Valve Installed at Orinda Filter Plant for 18 Years' Service

YEAR	Cost of Repairs	Valves Repaired	Cost per Valve Repaired	Cost per Valve Installed	Years in Service
1954	3926.20	11	356.93	122.69	18
1953	223.00	2	111.50	6.97	17
1952	89.38	1	89.38	2.79	16
1951	3654.10	20	182.71	114.19	15
1949*	232.13	1	232.13	7.25	13
1948	696.39	3	232.13	21.76	12
1946	464.26	2	232.13	14.51	10
1941	4642.60	20	232.13	145.08	5

* The average cost per valve repaired ($232.13), for the period 1951 through 1954 was used to estimate the cost of repairs between 1941 and 1949 at current prices.

Tentative Schedule Technical Committee Meetings at Chicago March 7-11



95% of Valve Repair—

(Continued From Page 71)

een years of service, the corrosion cost on each bronze mounted valve investigated has increased at a greater rate than the depreciation reserve.

Figure 2 shows a comparison between the estimated operating costs of a new 20-inch bronze trimmed gate valve with those of two different Monel trimmed valves. The curves for the Monel trimmed valves are shown as straight lines, representing the purchase price, because corrosion repairs would not be expected on this type of valve. After the bronze valve has been in service for five years, it will be equal in cost to one of the Monel trimmed valves. From this curve it can be estimated also that after 22 years' service the bronze trimmed valve will be equal in cost to the second Monel trimmed valve. For future installations it is suggested that Monel trimmed valves be considered over bronze trimmed valves.

Causes of Corrosion

Corrosion in this case is the result of galvanic action between the metals used in construction of the valves. For explanation, a sketch of the working parts of this valve has been prepared and is shown in Figure 3. As received from the manufacturer, the valve parts consist of cast iron discs with bronze seat rings, bronze stem and nut, bronze wedges, bronze wedge hooks and bronze studs and links. In each case the deterioration of the cast iron discs takes place near the point of contact of the bronze and cast iron, the corrosion being limited to small areas by the high resistivity of the water. Galvanic currents, which are generated by the bronze and cast iron, flow from the cast iron through the water to the bronze and through the bronze back to the cast iron. As the current leaves the cast iron, it carries iron ions into solution which forms a

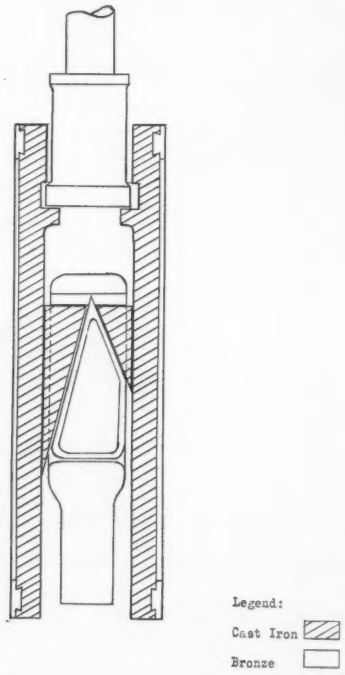


Figure 3 — Internal working parts of 20-inch valve.

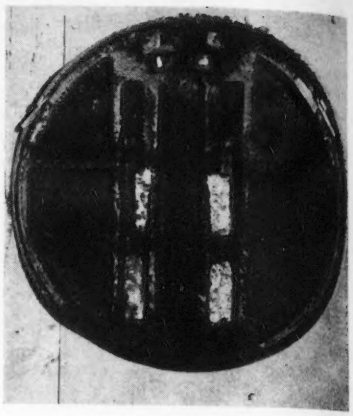


Figure 4 — Round disc from No. 2 washwater valve as removed for repairs August 1954. White spots are metal build-ups from cast iron welding rod. Repaired in 1941, 1948, and 1951.

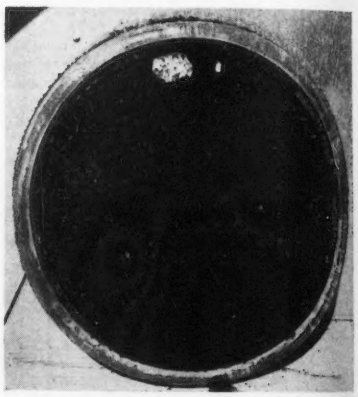


Figure 5 — Round disc from No. 2 washwater valve as removed for repairs. Reverse side of Figure 4. Old patch and new hole shown at top of disc.

film of ferrous hydroxide at the surface of the cast iron. If the film is left undisturbed, the ferric ions will combine with the oxygen in the water to form a ferric oxide tubercule, which will reduce the corrosion. Where there is sliding contact, the film is continually being cleaned away by the rubbing action of the bronze parts before the tubercules are formed, allowing the corrosion to continue at its initial rate.

Figures 4 and 5 are photographs of the round disc from the No. 2 washwater valve as it was removed for repairs in August 1954. The white sections are metal build-ups from cast iron welding rods, which substantiates the evidence in Table 1 that the valve was repaired in 1941, 1948 and 1951.

The rectangular white sections in the center of the disc in Figure 4 are the sliding planes for the bronze wedges and just below these are the areas of contact of the bronze hooks. Corrosion of these sections causes leaking or sluggish valve operation and if they are weakened too much will cause the disc to crack. The bright white spot in the stem nut recess is a new hole eaten out by galvanic action between the bronze stem nut and cast iron and the dull spot in the opposite corner is an old patch from past repairs. These two spots are

(Continued on Page 73)

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95% of Valve Repair—

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clearly shown in Figure 5, which is the opposite side of the disc. Another common point of failure is shown by the white metal on the rim of the disc in the immediate area of the bronze links and studs. Corrosion weakens this section to such an extent that the studs pulls through the rim. This allows the discs to drop apart, making the valve inoperative. As shown in the photograph, this section has been built up by cast iron welding rod, retapped and stainless steel studs substituted for the original bronze studs.

Figures 6 through 11 are photographs of the discs from the No. 1 washwater valve. Table 1 shows repairs were made on this valve in 1941, 1946, 1951, 1952 and 1954 (five times since installation).

Figure 6 is a picture of the square bottom disc as it was removed for repairs. The heavy build up of corrosion products is clearly shown, and the outline of the bronze hook is easily discernible. In Figure 7, the deep pits show up after removing the corrosion products by sandblasting. Pitting is most noticeable near the wedging plane and at the stem nut recess. Compare the thickness of the cast iron section at the top of the stem nut recess in Figure 7 with that in Figure 4. This section in Figure 4 was built up by cast iron welding rod during a previous repair.

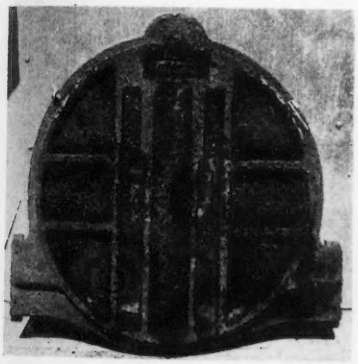

Figure 6—Square bottom disc from No. 1 washwater valve as removed for repairs September 1954. Valve repaired in 1941, 1946, 1951 and 1952.

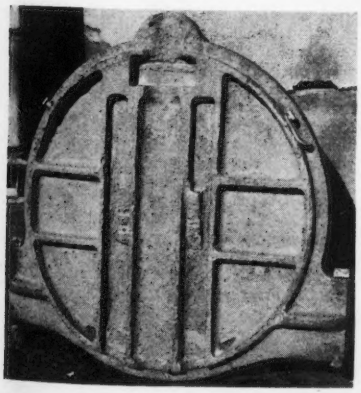

Figure 7—Same disc as shown in Figure 6 after sandblasting. Heavy pitting in area of bronze wedges and hooks. Build-ups of metal on rim near bronze studs and links. Note metal removed from top of stem nut recess.

Figures 8 and 9 show the round disc from the No. 1 washwater valve, before and after sandblasting. In Figure 9 the outline of the bronze hook is shown by heavy pitting in the vertical sections. The stem nut recess shows the same localized attack as in Figure 7.

In Figures 10 and 11 the discs were placed side by side and photographed in order to show the irregular shape of the stem opening, which was caused by galvanic currents. At the top of Figure 10 note the original location of the bronze studs, the patch weld on the rim after bronze studs pulled through and the location of the stainless steel studs which replaced the bronze.

Conclusions

Ninety-five percent of the repairs on the 20-inch gate valves in the old section of the Orinda Filter Plant were caused by corrosion.

In 3¾ years of operation the cost of corrosion on the valves amounted to 68 percent of the original investment.

In 18 years of service the estimated cost of corrosion is equal to 95 percent of the original purchase price.

In five years of service necessary repairs of corrosion damage on a new 20-inch bronze trimmed gate valve would make it equal in cost to one type of 20-inch Monel trimmed gate valve.

In 22 years of service necessary repairs of corrosion damage on a new 20-

(Continued on Page 74)

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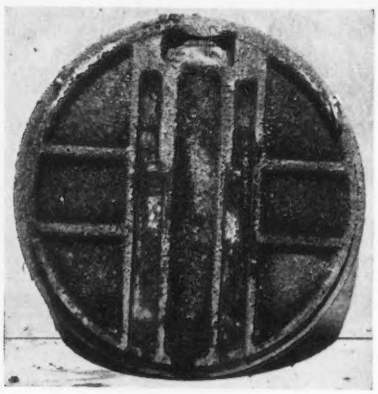

Figure 8 — Round disc from No. 1 washwater valve as removed for repairs September 1954. Heavy corrosion products over entire surface of disc.

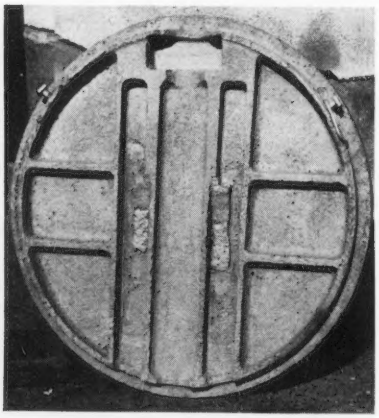

Figure 9 — Same disc as in Figure 8 after sandblasting. Heavy pitting in same areas as disc in Figure 7.

Figure 10 — No. 1 washwater valve discs as removed for repairs September 1954. Note heavy build-ups of corrosion products.

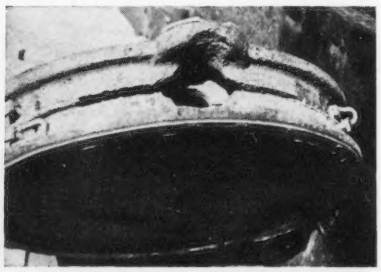

Figure 11 — Same discs as shown in Figure 10 after sandblasting. Note irregular outline of stem opening and new location of studs.

95% of Valve Repair–

(Continued From Page 73)

inch bronze trimmed gate valve would be equal in cost to another type of 20-inch Monel trimmed gate valve.

Recommendations

It is recommended that each valve be replaced with a Monel trimmed rubber seated butterfly valve, whenever repairs are required.

In future installations of this type, only valves mounted with Monel or stainless steel and high nickel cast iron are recommended for consideration.

TABLE 4

Depreciated Value and Actual Cost Due to Corrosion, of 20-Inch Gate Valve for 18 Years' Service

Year	Depreciated Valve*	Average Repair Cost per Valve Installed	**Actual Valve Cost	Years in Service
36	358.44	.....	358.44	0
37	353.46	.....	.....	1
38	348.48	.....	.....	2
39	343.50	.....	.....	3
40	338.52	.....	.....	4
41	333.54	63.37	421.81	5
42	328.56	.....	.....	6
43	323.58	.....	.....	7
44	318.60	.....	.....	8
45	313.62	.....	.....	9
46	308.64	8.87	430.68	10
47	303.66	.....	.....	11
48	298.68	14.83	445.51	12
49	293.70	5.20	450.71	13
50	288.72	.....	.....	14
51	283.74	114.19	564.90	15
52	278.76	2.79	567.69	16
53	273.78	6.97	574.66	17
54	268.80	122.69	697.35	18

* Depreciation rate $4.98 per valve per year.
** Actual valve cost due to corrosion.

Chicago Section Forms Coatings Committee

Chicago Section has organized a local section level technical committee on protective coatings. Lewis Zedra of the General American Transportation Corporation, East Chicago, Indiana has been elected chairman of the committee and Ralph E. Bowers of the Industrial Coatings Corporation, Chicago, Illinois has been elected secretary. Organizational meeting of the local section committee was held on December 7. This meeting was attended by 10 members of the Chicago Section. The scope of the committee is as follows:

Recognizing a tremendous technological development in the field of coatings, the primary purpose of the committee shall be to acquaint its members with these developments and their applications by means of discussion of corrosion problems relating to design, materials, surface preparation and application. Secondly, to accomplish this last mentioned purpose, the committee shall promote the exchange of information for the mutual benefit of the membership.

Chicago Section currently is organizing a local section committee on cathodic protection of underground structures. A third group to be organized will be of a general corrosion problem nature.

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A five-year index to CORROSION's Technical Section was published in December, 1950.

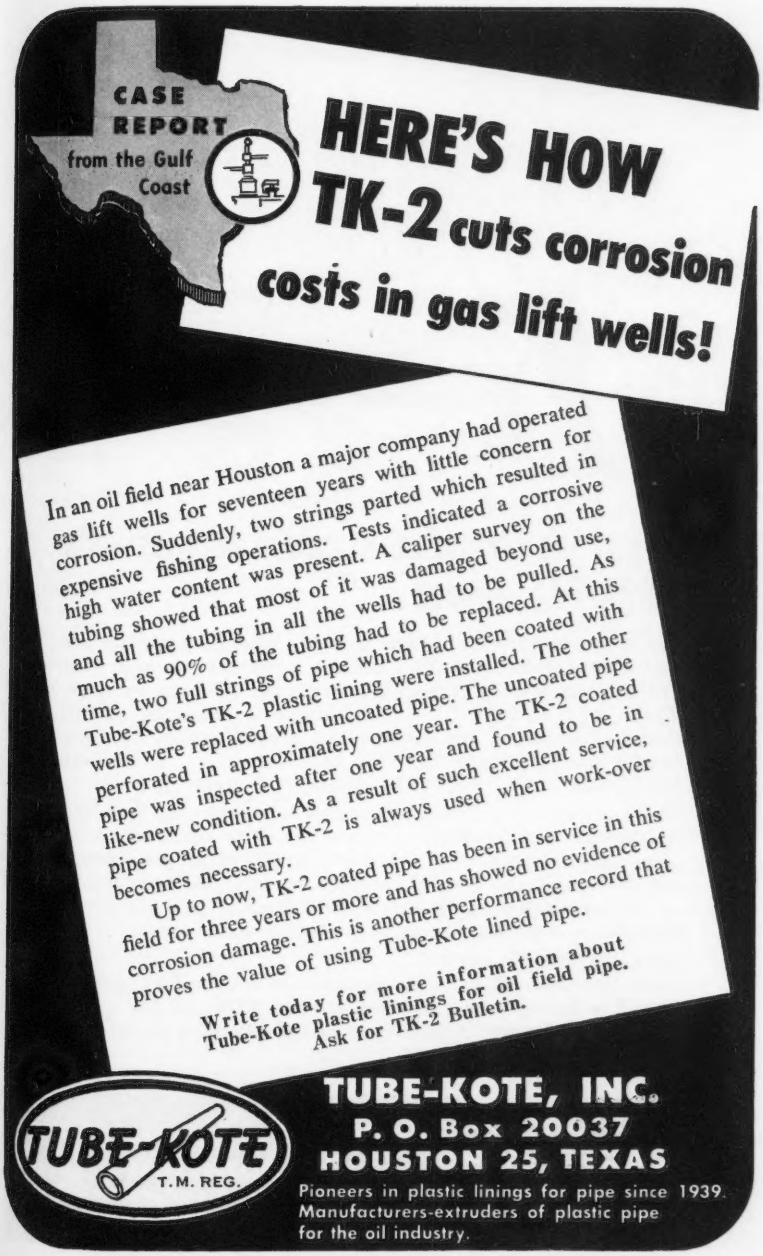
Utilities Materials Unit Now Headed by Ashline

Robert R. Ashline of the Department of Water & Power, Los Angeles, California is the new chairman of NACE Technical Unit Committee T-4F on Materials Selection for Corrosion Mitigation in the Utility Industry. Mr. Ashline takes over the chairmanship succeeding David Hendrickson, who retired recently from active duty with the East Bay Municipal Utility District in Oakland, California. Mr. Hendrickson has accepted a position with the Hinchman Corporation in Detroit, Michigan and will join the company soon.

Mr. Hendrickson was responsible primarily for the formation and organization of committee T-4F. The committee was formed shortly before the 1954 NACE Annual Conference in Kansas City and held its organizational meeting at the conference. Since the first meeting the committee has held two additional meetings and has become one of the more active NACE technical committees.

Symposium Cancelled

Under "Technical Program" in the Tentative Technical Committee Meeting Schedule published in this section of Corrosion in January, a symposium entitled "Petroleum Production Metallurgy" was shown to be scheduled for 9 a.m. and 2 p.m. Wednesday, March 9. This symposium has been cancelled from the technical program.


CASE REPORT
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TK-2 cuts corrosion costs in gas lift wells!
In an oil field near Houston a major company had operated gas lift wells for seventeen years with little concern for corrosion. Suddenly, two strings parted which resulted in expensive fishing operations. Tests indicated a corrosive high water content was present. A caliper survey on the tubing showed that most of it was damaged beyond use, and all the tubing in all the wells had to be pulled. As much as 90% of the tubing had to be replaced. At this time, two full strings of pipe which had been coated with Tube-Kote's TK-2 plastic lining were installed. The other wells were replaced with uncoated pipe. The uncoated pipe perforated in approximately one year. The TK-2 coated pipe was inspected after one year and found to be in like-new condition. As a result of such excellent service, pipe coated with TK-2 is always used when work-over becomes necessary.
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Henke Is New Head of Water Meter Committee

R. W. Henke, Badger Meter Manufacturing Co., Milwaukee, Wisconsin, recently appointed chairman of the new task group T-4F-1 on Water Meter Corrosion, has announced his proposed plans for the work of the group. One of the first steps will be to contact water works or interested personnel willing to participate in the project. To this end, anyone interested in the project should contact Mr. Henke at 2371 North 30th Street, Milwaukee 45, Wisconsin. The second phase will be to determine what corrosive attack occurs, including such things as what parts are affected, frequency of service of each part, what type of attack occurs and other factors involved in the corrosion of water meters. The third phase of the program will be the investigation phase. This will be an investigation of why the types of attack observed actually occurred. Included in the study will be materials of construction and water analyses. Final phase of the assignment will be the investigation of the problems and techniques of corrosion prevention to mitigate the corrosion.

HENKE

Mr. Henke is currently chief mechanical engineer, research and development division of the Badger Meter Manufacturing Co. Formerly he was project engineer with the Heil Company. He received a BS MS in Mechanical Engineering from the University of Wisconsin, is a registered profession engineer in Wisconsin. He is a member of NACE, ASM, ISM and ASTM, where he is a member of the ASTM committee on hard rubber materials. He is the author of several papers on meters and chemical proportioners. He recently received the 1954 Gray Iron Founders Societies Award of Redesign.

Gulf Coast Cooling Water Stress Corrosion Studied

Investigation of stress corrosion cracking in Gulf Coast cooling waters is the assignment of a new study group set up within the organization of Task Group T-5C-1 on Corrosion by Gulf Coast Cooling Waters. Charles P. Dillon, Carbide & Carbon Chemicals Co., Texas City has been appointed chairman of this study group on stainless and nonferrous metals. Mr. Dillon reports the program for investigation of stress corrosion cracking in Gulf Coast cooling waters is well underday.

The study group hopes to establish through a long term cooperative field test program the susceptibility of appropriate alloys to stress corrosion cracking in Gulf Coast cooling waters. It is believed if data can be established on the effects of alloy composition, stress levels and water analyses, a significant advance will have been made in

(Continued on Page 76)

Corrosion in Nuclear Reactors Is Discussed

Corrosion is significant in nuclear reactors because when corrosion products deposit on heat transfer surfaces efficiency is reduced and because they become radioactive, and also because their presence in the primary cooling system outside the nuclear reactor restricts access to the external system for maintenance. The result of these consequences has led to efforts to reduce the volume of corrosion products formed and to develop procedures for removing them from operating systems.

Corrosion, as it is understood in connection with the perforation of boilers, hot water tanks and pipelines is not the major concern in the nuclear power business.

The following is a discussion by R. F. Koenig of the Materials Engineering Section, Knolls Atomic Power Laboratory, Schenectady, New York on the article "High Purity Water Corrosion Resistant Materials Are Discussed," published beginning on page 91 in the Technical Committee News Section of the January issue of Corrosion Magazine. Mr. Koenig says that Dr. Roebuck has presented an excellent summary of the high temperature water corrosion work performed prior to 1954 and that his general recommendations are basic to good system design. However, since Dr. Roebuck completed his work, intensified corrosion testing has continued for the support of advanced, water-cooled nuclear reactors.

Recent investigation on some of the materials discussed in Dr. Roebuck's talk revealed that nickel and nickel-base alloys are attacked less in water containing dissolved hydrogen than in water containing oxygen and that these alloys show promise of satisfactory performance.

Carbon steels under static and quasi-static conditions show lower descaled corrosion rates than when exposed to high coolant velocities. From this recent information it is revealed the protective film on carbon steel is less resistant to erosion than that on stainless steel.

The lowest corrosion rates for stainless steel have been found with specimens which had been electropolished before testing. This may be attributable to the reduction in total surface areas. Ordinarily, corrosion rates are figured on projected areas and no allowance is made for the greater absolute areas of rough surfaces. As a result, the apparent corrosion rates are lower for smoother surfaces.

It has been found that sensitized and pickled Type 304 stainless steel corrodes at a much higher rate than solution-treated and pickled 304. However, sensitized Type 304 stainless steel resists attack in high temperature water as well as 347. It is deduced from this that care should be taken in pickling systems fabricated from 304.

Aside from water, is has been found recently that samples of stainless steel exposed to impure sodium can be cracked by bending, even though there had never been the slightest indication of stress corrosion. It is recommended that typical specimens be bent after exposure to check for embrittlement. Like most questions involving corrosion, each material application for pressurized, high temperature water must be analyzed in the light of the conditions attending the application. Generalized corrosion data should not be applied to specific design problems.

Gulf Coast Cooling—

(Continued From Page 75)

the understanding of this type of failure.

The committee plans to test Type 304 stainless steel, Type 316 stainless steel, Type 329 stainless steel, Carpenter 20, 16 Cr.-16 Mn-1 Ni, Alloy 803 and Inconel at the yield point and at two increments of the yield strength. The two increments will be one-third and two-thirds of the yield strength after prestressing to achieve a linear stress-strain relationship. The specimens will be miniature tensile specimens stressed against a supporting frame on a test rack designed by the committee. The racks will be assembled at the Texas City plant of Carbide and Carbon Co. and subsequently distributed to 19 companies represented on the committee for long term immersion exposures in brackish cooling waters. Evaluations will be made jointly by T-5C-1 members from six plants.

Anderson Medal Given

Charles S. Leopold, Philadelphia heating and air conditioning consulting engineer has been awarded the F. Paul Anderson Medal, highest award of The American Society of Heating and Ventilating Engineers.

"I got the idea from Standard Magnesium's VIBRA-PAK Anodes . . ."

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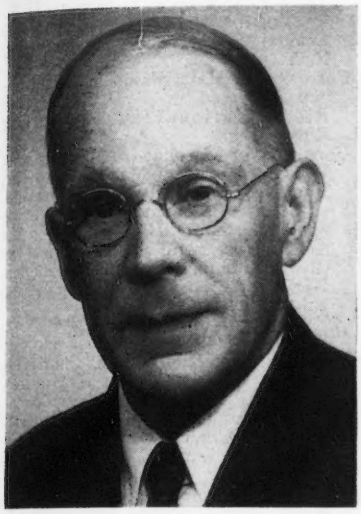

W. H. J. Vernon

Gordon N. Scott

Eminent British and American Scientists to Receive Whitney and Speller Awards for 1955

Two scientists who have made significant contributions toward a better understanding of how corrosion may be controlled have been selected to receive the 1955 National Association of Corrosion Engineers' Awards. Dr. W. H. J. Vernon best known among corrosion workers for his work on atmospheric corrosion will receive the Willis Rodney Whitney Award. Dr. Gordon N. Scott whose work on corrosion mitigation dates back to 1928, will receive the Frank Newman Speller Award. The Whitney Award is in recognition of contributions to corrosion science and the Speller Award in recognition of achievements in corrosion engineering.

They will be the ninth recipients of the awards which were established and first presented by NACE in 1947 honoring the persons after whom they are named.

Presentation of the awards will be by W. F. Rogers, Gulf Oil Corp., Houston immediate past-president of NACE and chairman of the awards committee. Presentation is scheduled during the NACE annual banquet to be held on Wednesday, March 9 at the Palmer House, Chicago.

Dr. Vernon has been engaged in consulting work since retiring as head of the Corrosion Group at Teddington, England in 1954. He graduated from the University of Birmingham, received a PhD (1924) and a ScD (1927) from London University and was awarded the Diploma of the Imperial College of Science and Technology. From 1913-1921 (excluding military service) he was a lecturer in metallurgy and metallurgical chemistry at Birmingham Technical School (now College of Technology). In 1921 he was appointed investigator to the Atmospheric Corrosion Research Committee and 1927 his work came directly under the Department of Scientific and Industrial research.

Dr. Vernon succeeded the late G. D. Bengough in 1936 as head of the Corrosion Group at Teddington. From this period until retirement he was responsible for direction and planning of work of the Group which became especially intensive during World War II. Work included development of improved accelerated corrosion tests which contributed to development of improved anticorrosive paints, discovery of new corrosion inhibitors for use in engine antifreeze solutions, packaging of metal components and temporary protectives. Also included was investigation into causes of underground corrosion and development of protective measures in the field.

Dr. Vernon was responsible for building up an active advisory service on corrosion problems available to government departments, public authorities and industry and in 1946 received the decoration of Officers of the Order of the British Empire for his war-time work.

He has been responsible as author or joint-author of some 60 published contributions and is author of A Bibliography of Metallic Corrosion (Arnold 1928) and the article Corrosion and Corrosion Prevention in Thorpe's Dictionary of Applied Chemistry.

Dr. Scott, consulting engineer in Los Angeles since 1936 received a AB (1922) and BS (cum laude 1922) in chemical engineering and a PhD (1926) in physical chemistry from the University of

(Continued on Page 78)

Eleven Symposia Are Scheduled for Chicago Conference

Following is a tentative and incomplete outline of the technical program to be given during the 1955 NACE 11th Annual Conference and Exhibition in Chicago, March 7-11. Order in which events and papers are listed is not necessarily the order in which they will be given.

Tuesday, March 8

Corrosion Principles Symposium

Oxide Films on Stainless Steels by T. N. Rhodin, E. I. du Pont de Nemours & Co., Wilmington, Del.

Principles Applicable to Oxidation and Corrosion of Metals and Alloys by W. W. Smeltzer, Alumiñium Laboratories, Ltd., Kingston, Ontario, Canada.

Chemical Inhibitors Symposium

Use of the Pearson Bridge in Corrosion Inhibitor Evaluation by E. J. Simmons, Sun Oil Co., Dallas.

The Development of a Standardized Laboratory Procedure for Screening Corrosion Inhibitors for Use in Oil and Gas Wells by J. C. Spalding, Jr., Sun Oil Co., Dallas and E. C. Greco, United Gas Corp., Shreveport.

Refinery Industry Symposium

Are You Presenting Your Refinery Corrosion Projects Effectively? by H. V. Nyland and C. W. Gomes, Sinclair Research Laboratories, Inc., Harvey, Ill.

Air Injection for Controlling Hydrogen Penetration of Steel by W. A. Bonner, and H. D. Burnham, Shell Oil Co., Wood River, Ill.

Organic Corrosion Inhibitors In Refinery Equipment by Charles Fiske and Paul Mernitz, Leonard Laboratories, Alma, Mich.

Oil and Gas Production Symposium

Use of Structural Plastic Products in Oil Production by W. M. Thornton, Atlantic Refining Co., Dallas and B. W. Bradley, Shell Oil Co., New York.

Corrosion Control on Offshore Drilling and Producing Equipment by Charles J. Fritts, Socony Paint Products Co., Houston.

Cathodic Protection of Oil Well Casings by Jack P. Barrett, Stanolind Oil & Gas Co., Tulsa.

Internal Casing Corrosion in Sour Oil Wells by J. A. Caldwell and M. L. Lytle, Humble Oil & Refining Co., Houston.

Effect of Water on Strength of Structural Plastics by W. H. Sharp and M. K. Weber, Shell Development Co., Emeryville, Cal.

(Continued on Page 78)

Technical Program—

(Continued From Page 77)

Educational Lecture No. 1. Some Important Considerations in the Selection and Use of Instruments for Corrosion Measurements by H. N. Hayward, University of Illinois, Urbana.

Wednesday, March 9

Chemical Industry Symposium

Corrosion by Valve Packing by L. M. Rasmussen, Manning, Maxwell and Moore, Stratford, Conn.

Design of Building for Corrosion Conditions by C. H. Topping, E. I. du Pont de Nemours & Co., Wilmington, Del.

Corrosion of Stainless Steel in Ferric Chloride Solutions by Herman A. Liebhafsky and Arthur E. Newkirk, General Electric Co., Schenectady, N. Y.

The Determination of the Effect of a New Grass Killer on Application Equipment by J. A. Kelly and W. J. Falkenstein, Dow Chemical Co. and J. R. Carr, Food Machinery and Chemical Corp.

The Pertechnetate Ion as an Inhibitor of the Corrosion of Iron and Steel by G. H. Cartledge, Oak Ridge National Laboratory, Oak Ridge, Tenn.

A Radiochemical Investigation of the Role of Mercury in the Corrosion of Aluminum by R. C. Plumb, M. H. Brown and J. E. Lewis, Aluminum Company of America, New Kensington, Pa.

A Practical Corrosion Service Program by B. J. Philibert, Olin Mathieson Chemical Corp., Baltimore.

Corrosion Testing of Aluminum. I. High Velocity Test Method Aqueous Solutions, and Corrosion Testing of Aluminum. II. Development of a Corrosion Inhibitor by S. B. Twiss and J. D. Guttenplan. Chrysler Corp., Highland Park, Mich.

Pipe Line General Symposium

Internal Plastic Coating of Pipe Lines in Place by J. C. Watts, Humble Pipe Line Co., Midland, Texas.

A Discussion of the Committee T-2D Report "Proposed Standard Method for Measuring Electrical Conductance of Coating on Buried Pipe Lines" by L. F. Heverly, Buckeye Pipe Line Co., Lima, Ohio.

Power and Communications Symposium

Atmospheric Galvanic Couple Corrosion by K. G. Compton, A. Mendizza and W. W. Bradley, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

Corrosion on the Florida Keys by R. W. Ackermann, American Telephone & Telegraph Co., Cincinnati and James P. McArdle, Jr., American Telephone & Telegraph Co., Atlanta.

Carbon Anode Installed in Electric Cable Conduit by H. L. Davis, Jr., Philadelphia Electric Co., Philadelphia.

The Use of Half Cells for Field Corrosion Testing by Robert Pope, Quakertown, Pa.

Educational Lecture No. 2. The Diagnosis of Corrosion Problems by V. V. Kendall, National Tube Division, U. S. Steel Corp., Pittsburgh.

Thursday, March 10

Cathodic Protection Symposium

Organization and Activity of the Corrosion Control Group of a Large Public Utility by J. W. McAmis, Washington Gas Light Co., Washington, D. C.

A Study of Protective Criteria on a Pipe Section in a Uniform Environment by L. P. Sudrabin, Electro Rust-Proofing Corp., Newark, N. J.

Instrumentation for Cathodic Protection by H. N. Hayward, University of Illinois, Urbana.

High Purity Water Symposium

Introduction to Symposium on Corrosion by High Purity Water by John F. Eckel, General Electric Co., Schenectady, N. Y.

Importance of High Purity Water Data to Industrial Applications by R. U. Blaser, Babcock & Wilcox Co., Alliance, Ohio.

Corrosion Resistance of Materials in High Purity Water by A. H. Roebuck, Continental Oil Co., Ponca City, Okla.

Corrosion Engineering Problems in High Purity Water by D. J. DePaul, Westinghouse Electric Corp., Pittsburgh.

Elevated Temperature Symposium

The Effect of Sodium Sulfate on the Oxidation of Alloy Steels at Elevated Temperatures by E. L. Simons, G. V. Browning and H. A. Liebhafsky, General Electric Co., Schenectady, N. Y.

Corrosion of Materials in Sodium, Lithium and Lead by W. D. Manly, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Corrosion of Gasoline Engine Exhaust Valve Steels by Max J. Tauscher, Thompson Products, Inc., Cleveland.

The Effect of Contamination by Vanadium and Sodium Compounds on the Air Corrosion of Stainless Steel by G. W. Cunningham and Anton deS. Brasunas, University of Tennessee, Knoxville.

Pipe Line Problem Clinic

Cathodic Protection Clinic, Charles L. Woody, United Gas Corp., Houston, discussion leader.

Pipe Lines and Storage Tanks Internal Corrosion Clinic, Ivy M. Parker, Plantation Pipe Line Co., Atlanta, discussion leader.

Pipe Lines Protective Coatings Clinic, L. A. Hugo, Phillips Petroleum Co., Bartlesville, Okla., discussion leader.

Protective Coatings Symposium

Application Techniques and Resistant Values of Catalytically Cured Phenolic Resin Coatings by Francis Ploederl, Wisconsin Protective Coating Co., Green Bay.

Organization and Administration of a Plant Painting Program by W. E. Chandler and C. W. Sisler, Monsanto Chemical Co., St. Louis.

The Investigation of an Unusual Cause of Shipbottom Pitting by R. P. Devoluy, Glidden Co., New York.

Application of Protective Coatings to Refinery Equipment by F. T. Radecke, Shell Oil Co., Wood River, Ill.

Educational Lecture No. 3. Fundamentals of Liquid Metal Corrosion by W. D. Manly, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Friday, March 11

Pipe Line Underground Roundtable.

General Corrosion Roundtable.

Eminent British—

(Continued From Page 77)

California. He is a registered professional engineer in chemical and electrical engineering in California.

From 1926-1927 he was plant superintendent of James Wakefield & Sons, Honolulu, research chemists for Mid-Continent Petroleum Corp., Tulsa 1927-1928. He was research associate for American Petroleum Institute at the National Bureau of Standards 1928-1934 where he studied corrosion mitigation in the oil industry and conducted nationwide tests of protective coatings on operating pipe lines. He was line technologist 1935-1936 for API in Dallas correlating information on pipe line corrosion. Dr. Scott is author or co-author of 23 technical publications and holds three patents. He also was an instructor during the University of California extension course titled Introduction to Corrosion.

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STOCKING AGENTS EVERYWHERE

Agenda for General Business Meeting Given

Following is the tentative agenda for the general business meeting scheduled to be held from 8:45 to 10:15 the morning of Tuesday, March 8, in Palmer House during the 1955 NACE 11th Annual Conference and Exhibition in Chicago.

President's Report, Aaron Watchter, Shell Development Co., Emerville, Cal., president.
Treasurer's Report, R. A. Brannon, Humble Pipe Line Co., Houston, treasurer.

Committee Reports

Policy and Planning Committee, E. P. Noppel, Ebasco Services, Inc., chairman.
Technical Practices Committee, H. W. Schmidt, Dow Chemical Co., Midland, Mich., chairman.
Publication Committee, R. B. Hoxeng, United States Steel Research Laboratories, Pittsburgh, chairman.
Regional Management Committee, L. A. Baldwin, Johns-Manville Sales Corp., New York, chairman.
Membership Control Committee, Aaron Wachter, Shell Development Co., Emeryville, Cal., chairman.
Committee on Education, Norman Hackerman, University of Texas, Austin, chairman.
General Conference Committee, L. W. Ewing, Jr., Standard Oil Company of Indiana, chairman.
Inter-Society Corrosion Committee, R. M. Wick, Bethlehem Steel Corp., Allentown, Pa., chairman.
Executive Secretary's Report, A. B. Campbell, Houston, executive secretary.

Some Booths Remain Available in Exhibition

Contracts for space in the Eleventh Annual NACE Exhibition have been signed by 76 firms through January 14. There are still some booths available. Those interested in investigating the advisability of exhibiting may obtain a brochure and contract specifications form from A. B. Campbell, executive secretary NACE, 1061 M & M Building, Houston 2, Texas.

The following exhibitors have signed contracts since the report published in January Corrosion:

American Coating & Supply Company
Binks Manufacturing Company
Deady Chemical Company
Harco Corporation
Hills-McCanna Company
Robert J. Kerr Chemicals, Inc.
Metallizing Engineering Company
Middle West Coating & Supply Company
Monsanto Chemical Company
The Natasco Company
Nicolet Industries, Inc.
Owens-Corning Fiberglas Corporation
Perrault Equipment Company
The Pfaudler Company
Pipeline Coating and Engineering Company, Inc.
Pipe Line Anode Corporation
Remco Manufacturing Company
Tnemec Company, Inc.
Wright Chemical Corporation

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Program Officials

H. L. BILHARTZ, Chairman
Technical Program Committee

EMIL G. HOLMBERG, Vice-chairman
Technical Program Committee

W. Z. FRIEND, Vice-chairman
Technical Program Committee

As chairman of the 1955 NACE Conference Technical Program Committee, H. L. Bilhartz, Production Profits, Inc., is responsible for selection of symposia officials and arrangements for Technical Committee and Symposia meetings. Emil G. Holmberg, Alloy Steel Products Co. and W. Z. Friend, International Nickel Co., Inc., are vice-chairmen.

F. N. ALQUIST
Vice-chairman,
General Corrosion
Roundtable

J. P. BARRETT
Chairman,
Pipe Line Underground
Roundtable

F. H. BECK
Vice-Chairman,
Educational Lectures

R. L. BULLOCK
Chairman, Pipe Line
Problem Clinic

W. P. CATHCART
Vice-chairman,
Protective Coatings

W. B. DELONG
Chairman,
Chemical Industry

A. O. FISHER
Chairman, General
Corrosion Roundtable

ED. C. GRECO
Chairman,
Oil and Gas Production

H. E. GREENWELL
Chairman,
Chemical Inhibitor

R. J. HAFSTEN
Vice-Chairman,
Refinery Industry

L. W. HARTKEMEIER
Chairman,
Educational Lectures

C. C. HARVEY
Vice-chairman,
Elevated Temperature

J. C. HOWELL
Vice-Chairman,
Cathodic Protection

R. B. HOXENG
Vice-chairman,
Corrosion Principles

T. J. MAITLAND
Vice-chairman, Power
and Communications

T. P. MAY
Chairman,
Corrosion Principles

L. O. McCORMICK
Chairman, Power
and Communications

W. B. MEYER
Chairman,
Protective Coatings

LLOYD B. NELSON
Vice-chairman,
Pipe Line Underground
Roundtable

W. F. OXFORD
Vice-Chairman,
Oil and Gas Production

IVY M. PARKER
Discussion leader,
Internal Corrosion
Clinic

FRANCIS W. RINGER
Chairman,
Cathodic Protection

A. H. ROEBUCK
Vice-chairman,
High Purity Water

LYLE R. SHEPPARD
Vice-chairman, Pipe
Line Problem Clinic

E. N. SKINNER
Chairman,
Elevated Temperature

F. M. WATKINS
Chairman,
Refinery Industry

CHARLES L. WOODY
Discussion leader,
Cathodic Protection
Clinic

BIOGRAPHIES
Program Officials

F. N. ALQUIST—Research chemist, Organic Research Division, the Dow Chemical Company. Dr. Alquist received his PhD from Purdue University. He was chairman of the NACE Editorial Review Sub-Committee and is chairman of NACE Unit Committee T-3C on Annual Losses Due to Corrosion and also vice-chairman of the General Corrosion Roundtable for the 1955 NACE Conference. Dr. Alquist long has been active in investigation of corrosion problems and has contributed many articles to technical journals.

JACK P. BARRETT—Research Group supervisor at the Research Center of Stanolind Oil and Gas Company since 1953. He joined the firm as a chemist in the Research Laboratories in 1945 and in 1949 was named technical group leader. In 1952 he was appointed technical group supervisor. All of his work with Stanolind has been in the field of corrosion, involving the laboratory development and field application of corrosion control methods. Mr. Barrett graduated from William Jewell College in 1938 with an AB in Chemistry. He is chairman of the Pipe Line Underground Roundtable to be held during the 1955 NACE Convention.

FRANKLIN H. BECK—Research assistant professor and assistant director of the Corrosion Research Laboratories at the Ohio State University Engineering Experiment Station. He received his BS in Metallurgical Engineering from the Pennsylvania State University in 1943, and was employed for two years at the E. I. Du Pont de Nemours and Company prior to entering the Graduate School of the Ohio State University where he earned his MS and PhD in Metallurgy in 1947 and 1949. His graduate research was concerned with corrosion and passivation studies of 18-8 stainless steel. Dr. Beck is the author and co-author of a number of corrosion articles, some of which have been presented at NACE Conferences and have appeared in Corrosion. He is vice chairman of the Educational Lecture program to be held during the 1955 NACE Conference.

H. L. BILHARTZ—President of Production Profits, Inc. He has served as senior chemical engineer in the Crude Oil Production Department of the Atlantic Refining Company, Dallas. Mr. Bilhartz received a BS from Southwestern University, majoring in chemistry and mathematics and did graduate work in electrical engineering at Harvard University and the Massachusetts Institute of Technology. He is active in the activities of The Natural Gasoline Association of America, NACE and is a member of the American Institute of Mining and Metallurgical Engineers. He is a past chairman of NACE Group Committee T-1 on Corrosion In Oil and Gas Well Equipment and is a member of several unit committees. Mr. Bilhartz is chairman of the Technical Program Committee for the 1955 NACE Conference.

ROBERT L. BULLOCK—Head of the Technical Services Section of Interstate Oil Pipe Line Company's Engineering Department. He also has served as corrosion engineer for his firm and has been associated with affiliates of Standard Oil Co. of New Jersey since 1935. Mr. Bullock holds a MS in electrical engineering from Texas A & M College. He is chairman of the Pipe Line Problem Clinic for the 1955 NACE Conference and has been active in NACE technical committees and otherwise. He organized Tulsa Section.

WALLACE P. CATHCART—President of the Tank Lining Corporation since its incorporation in 1950. He received an AB from Washington & Jefferson College. Mr. Cathcart joined Cathcart & Moore Company, a nonferrous metal and chemical sales company in 1947 and still is active in the firm. He has been a member of NACE since 1950 and is treasurer of the Pittsburgh Section and vice chairman of the Protective Coatings Symposium for the 1955 NACE Convention.

W. B. DeLONG—A member of the Engineering Department, Experimental Station of E. I. Du Pont de Nemours & Co., Ltd., in Wilmington, Delaware. He is chairman of the Chemical Industry Symposium for the 1955 NACE Conference and a member of Unit Committee T-1G on Sulfide Stress Corrosion Cracking.

D. J. DePAUL—Has been associated with the Westinghouse Atomic Power Division for the past six years, during which time he has been responsible for work on many of the corrosion problems connected with the company's reactor development program. He formerly was employed at Battelle Memorial Institute. Mr. DePaul received a BS in chemistry from Ohio State University in 1945. He organized and is chairman of NACE Unit Committee T-3F on High Purity Water and is also chairman of the High Purity Water Symposium to be held during the 1955 NACE Conference.

A. ORMAN FISHER—Corrosion engineer for the Merrimac Division, Monsanto Chemical Co. Since April 15, 1954 he has been engaged on company-wide corrosion problems in Monsanto's main office in St. Louis. Mr. Fisher holds a BS in chemical engineering from Northeastern University, Boston, Mass. He is chairman of the General Corrosion Roundtable for the 1955 NACE Conference.

EDWARD C. GRECO—Senior research chemist, Research Department, United Gas Corporation. He has been in corrosion work over 15 years. During World War II he was chief explosives chemist for U. S. Army Ordnance and special chemist, Development, of the Explosives Division of E. I. Du Pont. Mr. Greco graduated with a BS in chemistry from Northwestern Louisiana State College in 1934. A member of NACE since 1946, he has served as vice chairman and is now chairman of Group Committee T-1 on Corrosion in Oil and Gas Well Equipment, is vice chairman of Unit Committee T-1K on Inhibitors for Oil and Gas Wells, secretary-treasurer of the South Central Region NACE and chairman of the Oil and Gas Production Symposium for the 1955 Annual NACE Conference. Mr. Greco is also chairman of the Natural Gasoline Association of America Plant Corrosion Committee, president-elect of the Louisiana Academy of Sciences, councilor of ACS and member of American Association for the Advancement of Sciences.

H. E. GREENWELL—Senior chemical engineer in the Production Department of the Atlantic Refining Company, Dallas. He has been with the firm since 1948 specializing in the solution of oil production problems. A graduate of the University of Tennessee. Mr. Greenwell currently is chairman of NACE Unit Committee T-1C on Sweet Oil Well Corrosion and chairman of the Chemical Inhibitor Symposium for the 1955 NACE Conference.

RAYMOND J. HAFSTEN—Assistant chief engineer of the Whiting Refinery Engineering Division of the Standard Oil Company. He graduated from the University of Alabama in 1937 with a BS in metallurgical engineering. Before entering the employ of Standard Oil he worked for the United States Steel Corporation, Firestone Steel Products Co. and Armour Research Institute. He will serve as vice chairman of the

(Continued on Page 82)

BIOGRAPHIES
Program Officials

(Continued From Page 81)

Refinery Industry Symposium at the 1955 NACE Conference.

LEONARD W. HARTKEMEIER—Associate professor of chemistry at Colorado School of Mines, Golden. He holds degrees in chemistry and chemical engineering from the University of Louisville, University of Minnesota and has done work at the University of Colorado. Since 1921 he has held various positions involving chemistry at universities, Minnesota State Highway Dept. and Northern Pacific Railroad. He has been an associate professor since 1935 and is a consulting chemical engineer. Among other organizations he is a member of NACE, ACS and several fraternities and chairman of the Educational Lecture Program for the 1955 NACE Conference.

CLARENCE C. HARVEY—Supervises corrosion and materials of construction work for Ethyl Corporation at Baton Rouge, La. He holds an MS in Chemistry from the University of Mississippi (1941) and his experience with corrosion in high temperature services includes such environment as chlorine, hydrogen chloride, sodium, lead, sodium-lead alloys, hydrocarbon cracking and sodium hydroxide. He is better known perhaps for his work in the field of organic coatings. Mr. Harvey will serve as vice chairman of the Elevated Temperature Symposium during the 1955 NACE Convention.

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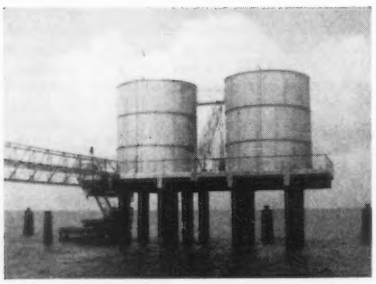

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J. J. HEGER—Engaged in research on stainless steels for United States Steel Corporation. He received a BS (1940) and MS (1948) from Carnegie Institute of Technology. From 1940 to 1945 he was employed by Babcock and Wilcox Co. Mr. Heger is a member of several NACE Unit committees and is vice chairman of the Chemical Industry Symposium to be held during the 1955 NACE Conference.

JOHN C. HOWELL—Electrolysis engineer for the Public Service Electric and Gas Company of New Jersey since 1937. In 1928 he was employed by the firm in the high voltage laboratory and upon completion of this work in 1932 was active in organizing a corrosion department. He graduated with an electrical engineering degree from Pratt Institute in 1925. Mr. Howell is chairman of NACE Task Group T-4B-3 on Tests and Surveys, is past chairman of Task Group T-4B-1 on Lead and Other Metallic Sheaths and is vice chairman of the Cathodic Protection Symposium for the 1955 NACE Conference.

R. B. HOXENG—Chief of the Chemical Metallurgy Division of Applied Research Laboratory, U. S. Steel Corporation, Prior to joining U. S. Steel he was associated with Case Institute of Technology. He did graduate work in physical chemistry at Iowa State College, the University of Pittsburgh and Case Institute (where he received a PhD in 1949). Dr. Hoxeng worked for the Manhattan Project and has done corrosion research at Iowa State College, the University of Chicago and for the Aluminum Company of America. He presently is chairman of NACE Publication ommittee, vice chairman of the Corrosion Principles Symposium scheduled during the 1955 NACE Conference and a member of Unit Committee T-4E on Analysis of Domestic Waters.

T. J. MAITLAND—Electrolysis and protection engineers, Long Lines Department, American Telephone and Telegraph Company. He holds an electrical engineering degree from Worcester Polytechnic Institute and has been engaged in corrosion mitigation work for over 30 years. He has been responsible for preparation of instructions covering corrosion testing methods and the construction of cathodic protection systems on cables installed or maintained by his company. Mr. Maitland has been an active member of NACE since its inception and is chairman of Task Committee T-4B-1 on Lead and Other Metallic Sheaths and vice chairman of the Power and Communications Symposium for the 1955 NACE Conference. He is the author of several papers presented at meetings of NACE and published in Corrosion.

LAWRENCE O. McCORMICK—Assistant engineer in the Testing Section of the Electric Distribution Department, Consolidated Gas, Electric Light & Power Company of Baltimore. He has been employed by this company since graduating from Johns Hopkins University in 1927 with a BE degree. Most of his time has been on electrolysis mitigation work on cable lines. A member of NACE since 1947, he presently is serving on Unit Committee T-4B on Corrosion of Cable Sheaths and is chairman of the Power and Communications Industry Symposium for the 1955 NACE Conference.

T. P. MAY—Technical manager of the Harbor Island and Cure Beach Test Stations of International Nickel Company. He served from 1947 as a member of the Corrosion Engineering Section of his firm. He was a member of the Research Staff of the Chemistry Division, Naval Research Laboratory from 1939-1947 being head of the Corrosion Section 1943-1947. Dr. May holds a BS in Chemical Engineering and a PhD in Physical Chemistry from Catholic University, Washington, D. C. A member of NACE since 1947, he served successively as vice chairman and chairman of the Metropolitan New York Section and vice chairman and chairman of the North East Region during the years 1948-52. He was a member of the Editorial Review Committee of NACE from 1951-1954 being chairman from May 1953-June 1954. He is now a member of the board of directors of NACE, vice chairman of the Publication Committee and chairman of the Corrosion Principles Symposium to be held during the 1955 NACE Conference.

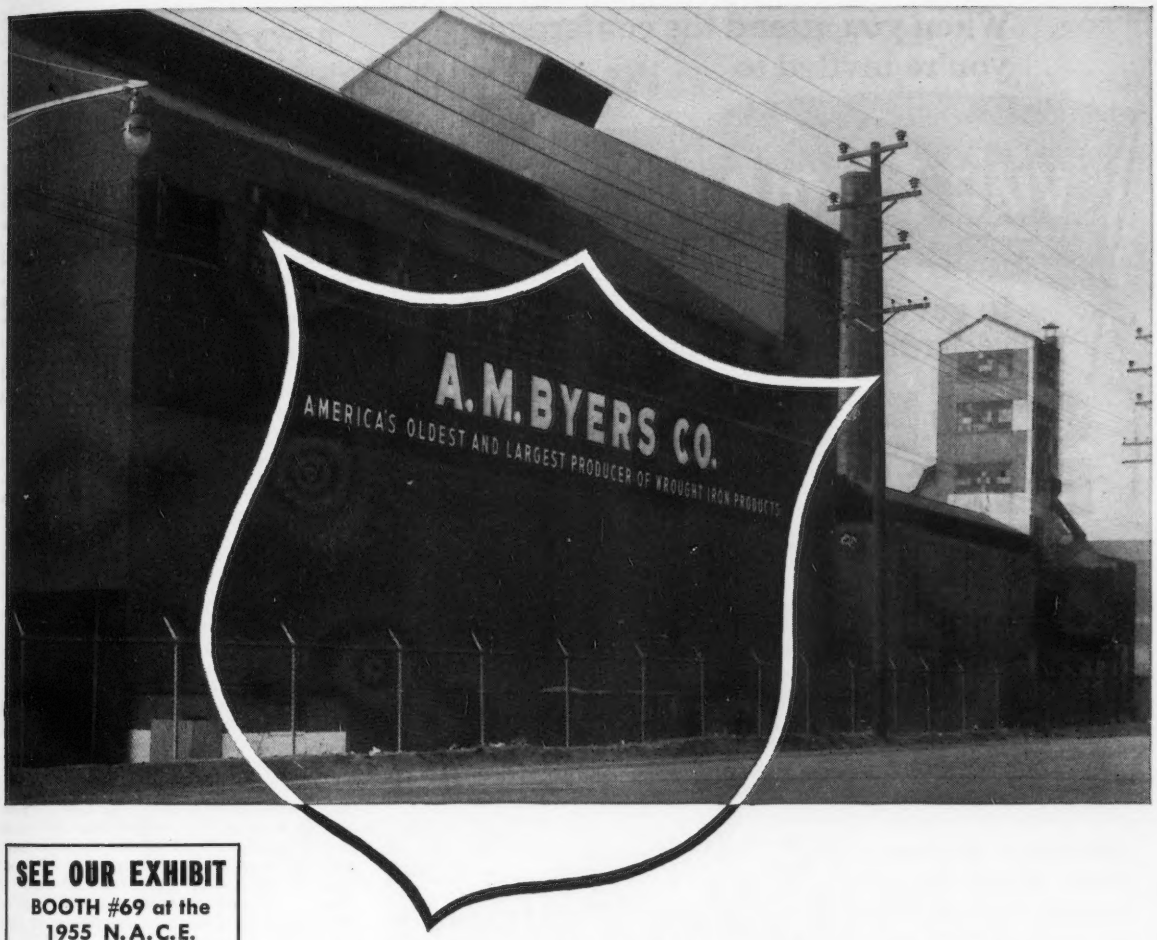
WALTER B. MEYER—President of the St. Louis Metallizing Company since 1952. He graduated from Illinois College, Jacksonville, Ill., in 1935. He was connected with the Metallizing Engineering Co., Inc., as sales and service engineer and later as Midwestern branch manager. From 1939 until 1945 he was associated with Nooter Corporation of St. Louis as manager of the Metallizing Division. During World War II Mr. Meyer was engaged by the Office of the Secretary of War to install metallizing equipment and train personnel of the Ordnance and Corps of Engineers in the China, Burma, India Theater of War and in the Mediterranean Theater of War. He is a member of the American Welding Society, Society of Plastics Engineers, American Metallizing Contractors Association and other technical organizations. A member of NACE since 1953, he is chairman of the Protective Coatings Symposium for the 1955 NACE Conference.

L. B. NELSON—Senior corrosion engineer, Shell Pipe Line Corporation, Houston. Prior to joining Shell in 1933 he was employed as testing engineer with Commonwealth Edison Company in Chicago and as transmission and field engineer with Public Service Company of Northern Illinois. He graduated with a BS in electrical engineering from Colorado University in 1928. He is vice chairman of the Pipe Line Underground Roundtable Symposium to be held during the 1955 NACE Conference.

W. F. OXFORD, JR.—Section Head in Corrosion Analytical Group, Production Research Laboratory, Gulf Coast Division, Sun Oil Company. He is engaged in oil and gas condensate well corrosion problems and salt water disposal studies. Mr. Oxford received his BS in chemistry from Texas A & M College where he also taught chemistry and did some graduate work. A member of NACE since 1950, he is vice chairman of Technical Group Committee T-1 on Corrosion in Oil and Gas Well Equipment and vice chairman of the Oil and Gas Production Symposium to be held during the 1955 NACE Conference.

IVY M. PARKER—Field technologist for the Plantation Pipe Line Company, Atlanta, since 1945. She received a AB from West Texas State Teachers' College and a AM and PhD from the University of Texas. She was assistant professor of chemistry at Mary Hardin-Baylor College 1934-1935, analytical chemist for the Shell Oil Company 1936-1943 and senior research chemist for the J. S. Abercrombie Company 1943-1945. Dr. Parker's fields of work include development of petroleum solvents, scale and corrosion control in refinery cooling water and internal corrosion of product pipe lines. A member of NACE since 1944 she is presently editor of Corrosion, chairman of Unit Committee T-2E on Internal Corrosion of Product Pipe Lines and Tanks and is discussion leader of the Pipe Lines and Storage Tanks Internal Corrosion Clinic scheduled to be held during the 1955 NACE Conference. Dr. Parker also is a member of the American Chemical Society, Institute of Chemists and Georgia Academy of Science.

(Continued on Page 84)



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BIOGRAPHIES
Program Officials

(Continued From Page 82)

FRANCIS W. RINGER—Consulting corrosion engineer. He received his BS in electrical engineering from the University of Oklahoma. He has been associated with corrosion control work for the Standard Oil Company of New Jersey, Oklahoma Pipe Line Company, Interstate Oil Pipe Line Company and Texas Eastern Transmission Company. A member of NACE since 1944 he is vice chairman of Unit Committee T-3d on Instruments for Measuring Corrosion, a member of Unit Committee T-2C on Minimum Current Requirements and chairman of the athodic Protection Symposium for the 1955 NACE Conference.

A. H. ROEBUCK—Engaged in study of production corrosion and related problems in the Development and Research Department of Continental Oil Company. Prior to joining this firm he was associated with the Atomic Energy Commision's atomic reactor development program at the Argonne National Laboratory where he was a member of the reactor engineering division. He was engaged in the study of the corrosion of stainless steel, zirconium and other metals for use at elevated temperatures. Dr. Roebuck received his MS from the University of Arizona and his PhD from the University of Texas. He is chairman of Technical Unit Committee T-3b on Identification of Corrosion products and vice chairman of the High Purity Water Symposium to be held during the 1955 NACE Conference.

LYLE R. SHEPPARD—Senior Engineer in Corrosion Research with Shell Pipe Line Corporation in Houston. He accomplished four years of undergraduate work at the Carnegie Institute of Technology and received a BS in industrial engineering from the University of Houston as well as taking graduate work in industrial engineering and metallurgy at that institution. A charter member of NACE, he currently is chairman of Task Group T-2A-1 on Galvanic Anode Operating Installations and T-3D-1 on Electrical Holiday Inspection of Coatings and is vice chairman of the Pipe Line Problem Clinic scheduled during the 1955 NACE Conference.

E. N. SKINNER, JR.—In charge of the High Temperature Materials Section, Development and Research Division, International Nickel Co., Inc., where his interests and activities have been principally in the area of alloy selection for various types of high temperature service. He received undergraduate and doctorate degrees from Yale University. He is presently chairman of NACE Task Group T-5B-1 on Exposure Tests and is chairman of the Elevated Temperature Symposium for the NACE 1955 Conference.

FRANKLIN M. WATKINS—Director of the Corrosion Division, Sinclair Research Laboratories, Inc., Harvey, Ill., since 1948. He holds a BS in chemical engineering and a MS in chemistry from the University of Colorado. While a testing engineer in General Electric Company's research laboratories he became interested in the properties of transformer oils and as a result was employed by Sinclair Refining Company's research deparmtent in 1946. He then directed additive synthesis and formulation of petroleum products with additives. Since joining NACE in 1949 he has been chairman of the Chicago Section and of Unit Committee T-3A on Corrosion Inhibitors. Mr. Watkins currently is chairman of Group Committee T-3, General and chairman of the Refinery Industry Symposium for the 1955 NACE Conference.

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Corrosion Principles

Oxide Films on Steel And Aluminum Are Topics of Session

Compositional properties of passive oxide films on Type 304 stainless steel, alloy composition and surface treatment on film compositions of Types 304, 316 and 347 stainless steels and growth and protective properties of films on aluminum and its alloys and other metals are considered in two papers to be given in the Corrosion Principles Symposium scheduled Tuesday March 8, the second day of the 11th Annual NACE Conference in Chicago. T. P. May, International Nickel Company, Inc., and Raymond B. Hoxeng, U. S. Steel Research Laboratory, are chairman and vice-chairman respectively.

That oxide film properties strongly indicate capacity of certain stainless alloys to develop corrosion-resistance surfaces in certain environments is concluded by one author. The second paper emphasizes role of lattice defects in governing diffusion of metal through film to react with environment.

Abstract

Oxide Films On Stainless Steels. By T. N. Rhodin.

Compositional properties of oxide films isolated from surfaces of stainless steels have been studied using specially developed microanalytical techniques. Properties of passive films on Type 304 stainless steel are evaluated and effects of alloy composition and surface treatment on film compositions of Types 304, 316 and 347 stainless steels studied.

Influence of corrosion in various media has been correlated with film compositional properties. Compostion of films after immersion in acids was found to be related to film composition prior to immersion. Effect of immersion depended on nature and intensity of corrosion and was reflected most sensitively by iron and silicon contents of films.

Conclusion is that film properties strongly indicate capacity of certain stainless alloys to develop corrosion-resistant surfaces in certain environments.

Abstract

Principles Applicable To Oxidation and Corrosion of Metals and Alloys. By W. W. Smeltzer.

Phenomenological basis of kinetic laws governing oxidation is described to illustrate manner of growth and protective properties of oxide films on metals. Metals are separated into groups forming "metal-excess" and "metal deficit" oxide films and emphasis is placed on role of lattice defects in governing diffusion of metal through film to react with environment. Effects of alloying elements on oxidation rates of metals are discussed in terms of formation of films consisting of heterogeneous mixtures and solid solutions of oxides and intramolecular oxides. Throughout review special reference is made to aluminimum and its alloys for illustrative examples.

Operhall Is Elected

Ted Operhall, Misco Precising Casting Co., Whitehall, Mich., was elected president of the Investment Casting Institute at the annual Fall meeting of ICI in Chicago on November 3-4. Vincent S. Lazzara, Castings Engineers, Inc., Chicago, was elected vice president during the meeting and Harry P. Dolan, Harry Dolan & Associates, was reappointed executive secretary.

RHODIN

SMELTZER

ABOUT THE AUTHORS

THOR N. RHODIN—Research engineer, Engineering Research Laboratory, Engineering Department, E. I. Du Pont de Nemours & Co., Inc., since 1950. He received his BS in chemistry from Haverford College in 1942 and a MS (1945) and PhD (1946) in physical chemistry at Princeton University. From 1946-1950 he was on the staff of the Institute for Study of Metals. Dr. Rhodin's fields of research are surface chemistry of metals, corrosion, michrotechniques, gas-adsorption and physical metallurgy.

W. W. SMELTZER—Member of the staff of the Chemical Division of Aluminium Laboratories, Limited, Kingston, Canada. He holds a BSc in chemistry from Queen's University, Kingston and a PhD in physical chemistry from the University of Toronto. Dr. Smeltzer has worked in the fields of heterogeneous catalysis and chemisorption at the National Research Council Laboratories, Ottawa, Canada. He is now doing work in the field of the formation of oxide film on aluminum and its alloys.

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Chemical Inhibitor

Pearson Bridge and Screening Are Topics

A circuit for measuring potentials of remote electrodes in presence of current flow and a standardized laboratory procedure for screening corrosion inhibitors for use in oil and gas wells are described in two papers to be presented at the Chemical Inhibitor Symposium scheduled on Tuesday, March 7, the second day of the 11th Annual NACE Conference to be held in Chicago. H. E. Greenwell, The Atlantic Refining Co., is chairman.

Information on basic operation of a Pearson bridge as well as data on effect of impressed current on potential of steel electrodes in various systems containing corrosion inhibitors is explained by author of one paper. The second paper provides information on a test being developed by Unit Committee T-1K on Inhibitors for Oil and Gas Wells.

Abstract

The Use Of The Pearson Bridge In Corrosion Inhibitor Evaluation. By E. J. Simmons. Basic operation of Pearson bridge, which is a circuit for measuring potentials of remote electrodes in presence of current flow is described. Data on effect of impressed current on potential of steel electrodes in various systems containing corrosion inhibitors are presented.

Certain oil-soluble inhibitors appear to form a film on metal surface which causes high rate of change of electrode potential with change in impressed current. Semi-quantitative relationship of the change called film resistance is demonstrated and adsorption and desorption rates can be determined from this relationship. Inhibitors which adsorb rapidly invariably give near 100 percent protection in weight loss tests, whereas those which adsorb more slowly show a percent protection which is dependent on relationship between adsorption time and duration of test. Water-soluble organic inhibitors do not exhibit this type of film which may actually be dependent on oil phase itself for formation.

Abstract

The Development of a Standardized Laboratory Procedure for Screening Corrosion Inhibitors for Use in Oil and Gas Wells. By J. C. Spalding and E. C. Greco. Although several ASTM and other methods for evaluating effect of an inhibitor on corrosion rate of various materials are available, none fit the peculiar needs for determining such effects in a corrosive medium consisting of oil, salt water and gas, all of which may be laden with CO_2, H_2S and organic acids. This particular corrosive medium occurs in producing oil wells in several areas of the United States. Exact simulation of medium is impossible but a test is being developed to at least indicate relative merit of various corrosion inhibitors under similar conditions. Method of procedure for developing such a test is presented and evolution from a myriad of various types of testing procedures is described.

Test is a static oil and water immersion type utilizing difference in weight loss of steel coupons when under influence of an inhibited system and weight loss when under influence of an uninhibited system as a criteria of corrosion protection.

Evolution of procedure and development of a standardized procedure has been the work of NACE Unit Commitee T-1K on Inhibitors for Oil and Gas Wells. Test will provide users and manufacturers of inhibitors with a common yardstick of a compound's relative effectiveness and as easy medium of interchange of information. This will, in the long run, reduce amount of duplicated effort, expense of long term field trials and will, in general be an aid in attaining the goal of effective and economical inhibition practices.

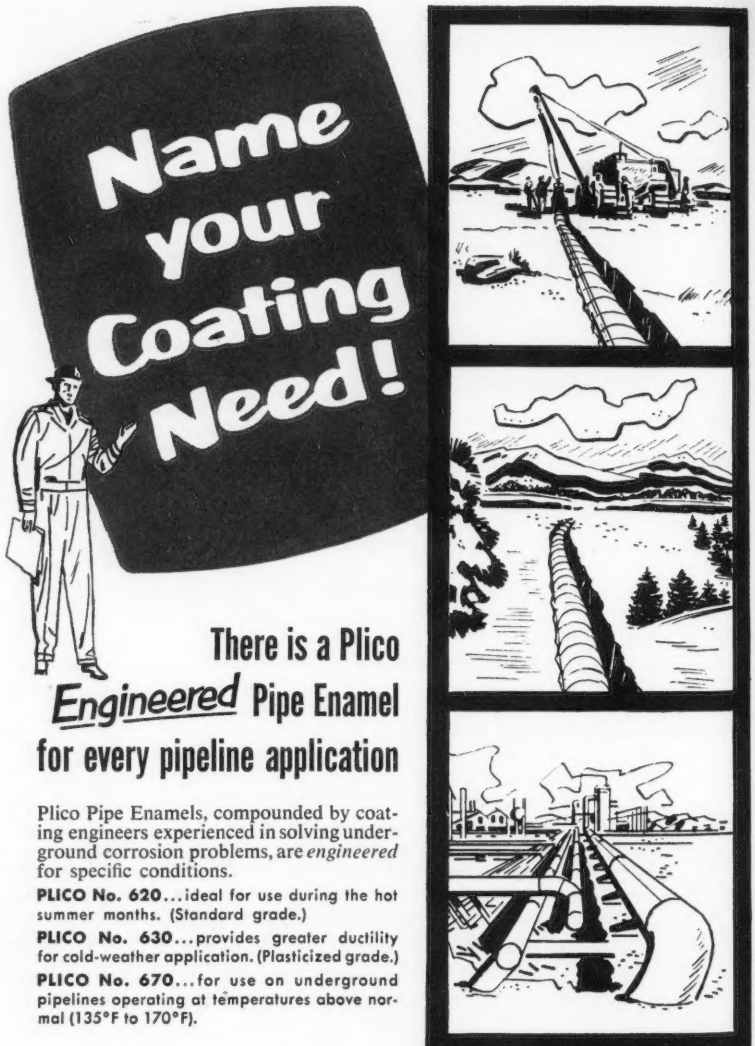
SIMMONS

SPALDING

ABOUT THE AUTHORS

EDWARD J. SIMMONS—Supervisor of chemical test section of Production and Research Laboratory, Sun Oil Company in Dallas. He graduated from Southern Methodist University with majors in chemistry and biology. A member of NACE, he presently is active on Unit Committee T-1C on Sweet Oil Well Corrosion and T-1K on Inhibitors for Oil and Gas Wells.

J. C. SPAULDING, JR.—Division materials and equipment engineer for Sun Oil Company, Southwest Division. Received a BS in basic engineering and a BS in chemical engineering from Georgia School of Technology. He joined Sun Oil in 1947 as field engineer working on drilling fluids and related oil production problems and at this time began study of oil field corrosion. He is a member of several NACE technical committees and is chairman of Unit Committee T-1K on Inhibitors for Oil and Gas Wells.



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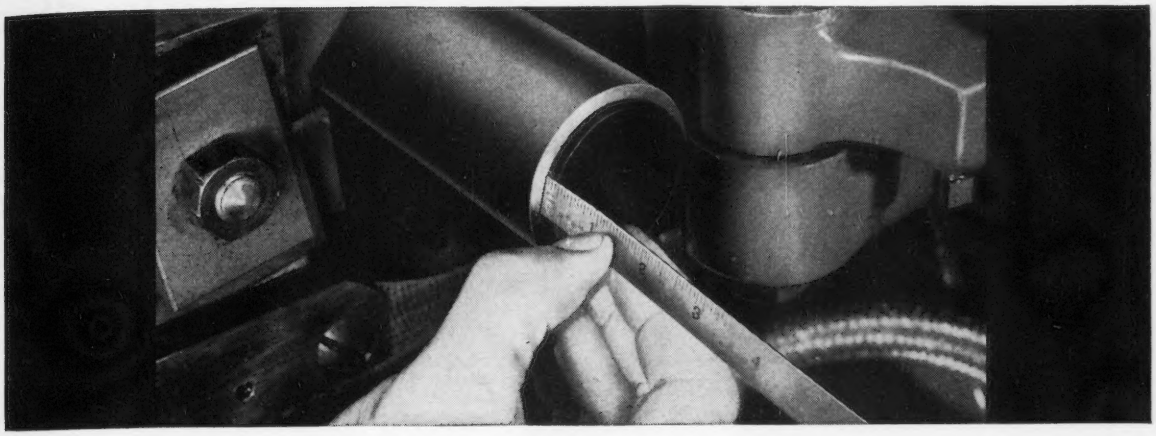

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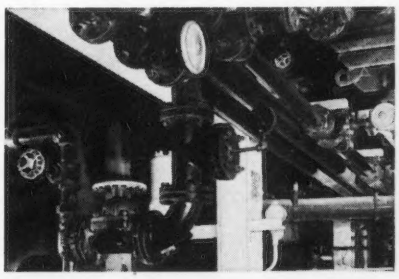
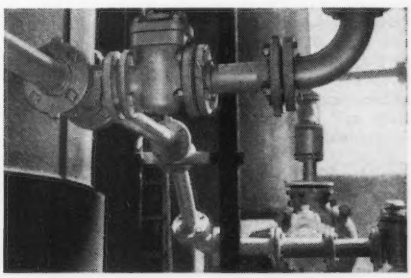


A large chemical company uses this installation to convey demineralized water. It has a perfect record of keeping the water free of contamination for five years!



Saran lined pipe used for conveying hydrochloric acid at temperatures from 20° to 90°C., has had no unscheduled interruptions due to corrosion for over two years!

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Refinery Industry

Economic Analysis Aids in Justifying Corrosion Program

Although corrosion prevention appears to have negative economic aspect when contrasted to usual projects such as improved refinery processes or production of new products the economic analysis form of presentation can be used in an understandable manner according to one of the three papers to be given in the Refinery Industry Symposium scheduled on Tuesday, March 8, the second day of the 1955 Annual NACE Conference in Chicago. F. M. Watkins, Sinclair Research Laboratories, Inc., and R. J. Hafsten, Standard Oil Co., are chairman and vice-chairman respectively.

Abstract

Are You Presenting Your Refinery Corrosion Projects Effectively? By H. V. Nyland and C. W. Gomes.

Economic analysis can show a corrosion engineer whether or not he is giving greatest emphasis to most difficult refinery corrosion problems. Management is well acquainted with these anlyses applied to new or improved refinery processes or to production of new products. As conventionally used, economic studies are summarized in terms of increased earnings to the company. Increased earnings may be expressed as return on investment or by capital payout period if new capital is involved. Corrosion prevention appears to have a negative aspect when contrasted to usual projects considered by management, however, same form of presentation can be used in an understandable manner.

Corrosion control projects frequently compete with many projects and presentation of corrosion program in conventional form helps place it in its proper relationship. Predicted earnings from successful corrosion control are real even though application of economic analysis may require somewhat obscure assumptions. Guiding principles for application of economic analysis to oil refinery operating problems are presented and illustrated by a specific example.

ABOUT THE AUTHORS

H. V. NYLAND—Director of the Economic Analysis Division of Sinclair Research Laboratories, Inc., Harvey, Ill. During World War II he was with the economics section of the Petroleum Administration for War in Washington, D. C. He holds an ScD in chemical engineering from the University of Michigan. Dr. Nyland is a member of the American Institute of Chemical Engineers, American Chemical Society and the National Association of Cost Accountants.

C. W. GOMES—Chemical engineer in the Economics Analysis Division of Sinclair Research Laboratories, Inc., Harvey, Ill. He holds a chemical engineering degree from the University of Illinois and is a member of the American Chemical Society.

Corrosion Discussion Set

A discussion of corrosion problems is included in the four-day conference of the California Municipal Utilities Association which is scheduled to be held in Sacramento, February 22-25.

NYLAND

GOMES

60 Technical Committees Plan Meetings in Chicago

Information about the 60 technical committees of NACE scheduled to meet during the 1955 NACE Annual Conference and Exhibition in Chicago appear in a table in the Technical Committee News section of this issue of CORROSION. Probable agendas of all technical committee meetings were published in the Technical Committee News section of January CORROSION.

Registration Time and Place for Conference

There will be no preregistration for the 1955 NACE Annual Conference and Exhibition scheduled in Chicago, March 7-11.

Following is tentative registration times and dates for the conference. Registrations will be taken on the fourth floor of the Palmer House in Chicago.

Sunday, March 6: 12 am—5 pm.

Monday, March 7, Tuesday, March 8: 8 am—5 pm.

Wednesday, March 9, Thursday, March 10: 9 am—5 pm.

Friday, March 11: 9 am—9:30 am.

Exhibition Opening and Closing Times Given

The list of exhibitors indicates that an extensive variety of corrosion control materials and processes will be on view during the 1955 NACE 11th Annual Conference and Exhibition scheduled at the Palmer House in Chicago, March 7-11.

Non-registrants must obtain guest passes from exhibitors in order to visit the exhibition.

Following is a tentative schedule of exhibition hours. Times opening and closing:

Tuesday, March 8; Wednesday, March 9; Thursday, March 10: 9 am—6 pm.

Friday, March 11: 9 am—12 am.

Benedict Delivers Lecture

Mason Benedict, professor of Nuclear Engineering in the Chemical Engineering Department, Massachusetts Institute of Technology, delivered the Sixth Annual Lecture of the American Institute of Chemical Engineers during the institute's 47th Annual Meeting in New York City, December 12-15. Mr. Benedict spoke on Nuclear Reactors for Research and indicated that principal use of reactors in research would include activation of analysis or wear studies.

TECHNICAL REPORTS

Remittances must accompany all orders for literature the aggregate cost of which is less than $5. Orders of value greater than $5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas.

Add 65c per package to the prices given below for Book Post Registry to all addresses outside the United States, Canada and Mexico.

TP-1 Report on Field Testing of 32 Alloys in the Flow Streams of Seven Condensate Wells (Pub. 50-3) NACE members, $8; Non-members, $10 per copy.

T-1A Survey of Corrosion Control in California Pumping Wells. A Report of T-1A on Corrosion in Oil and Gas Well Equipment, Los Angeles Area. Pub. 54-7. Per copy, $.50.

T-1G Sulfide Corrosion Cracking of Oil Production Equipment. A Report of Technical Unit Committee T-1G on Sulfide Stress Corrosion Cracking. Pub. 54-5. $.50 Per Copy.

TP-2 First Interim Report on Galvanic Anode Tests. (Pub. 50-2) NACE members, $3; Non-members, $5 per copy.

T-2C Some Observations of Cathodic Protection Potential Criteria in Localized Pitting. A Report of T-2C on Minimum Current Requirements for Cathodic Protection. Pub. 54-2. Per Copy $.50.

TP-3 First Interim Report on Ground Anode Tests. (Pub. 50-1) NACE members, $3; Non-members, $5 per copy.

T-4B-3 Tests and Surveys for Lead Sheathed Cables in the Utilities Industry. Second Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths. Publication 54-6. Per Copy $.50.

T-4B-4 Pipe-Type Cable Corrosion Protection Practices in the Utilities Industry. First Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths. Publication 54-3. Per Copy $.50.

TP-1D Sour Oil Well Corrosion. *Corrosion* August, 1952, issue. NACE members, $.50; Non-members $1 per copy.

TP-1G Field Experience With Cracking of High Strength Steel in Sour Gas and Oil Wells. (Included in Symposium on Sulfide Stress Corrosion. (Pub. 52-3) $1 per copy. 5 or more copies to one address, $.50 per copy.

TP-5A Materials of Construction for Handling Sulfuric Acid. *Corrosion*, August, 1951, issue. NACE members, $.50; Non-members, $1 per copy.

TP-5C Stress Corrosion Cracking in Alkaline Solutions. (Pub. 51-3) Per Copy, $.50.

T-6A Application Techniques, Physical Characteristics and Corrosion Resistance of Polyvinyl Chlor-Acetates. A Report of Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. Publication 54-4. Per Copy, $.50.

TP-6G First Interim Report on Recommended Practices for Surface Preparation of Steel. (Pub. 50-5) Per copy, $.50.

TP-6G Second Interim Report on Surface Preparation of Steels for Organic and Other Coatings. (Pub. 53-1) Per copy, $1; five or more copies to one address, per copy $.50.

TP-12 Report on Electrical Grounding Practices. Per copy $.50.

TP-19 Corrosive Effects of Deicing Salts—A Progress Report by Technical Practices Committee 19. *Corrosion*, January, 1954, issue. NACE members $.50; Non-members $1 per copy.

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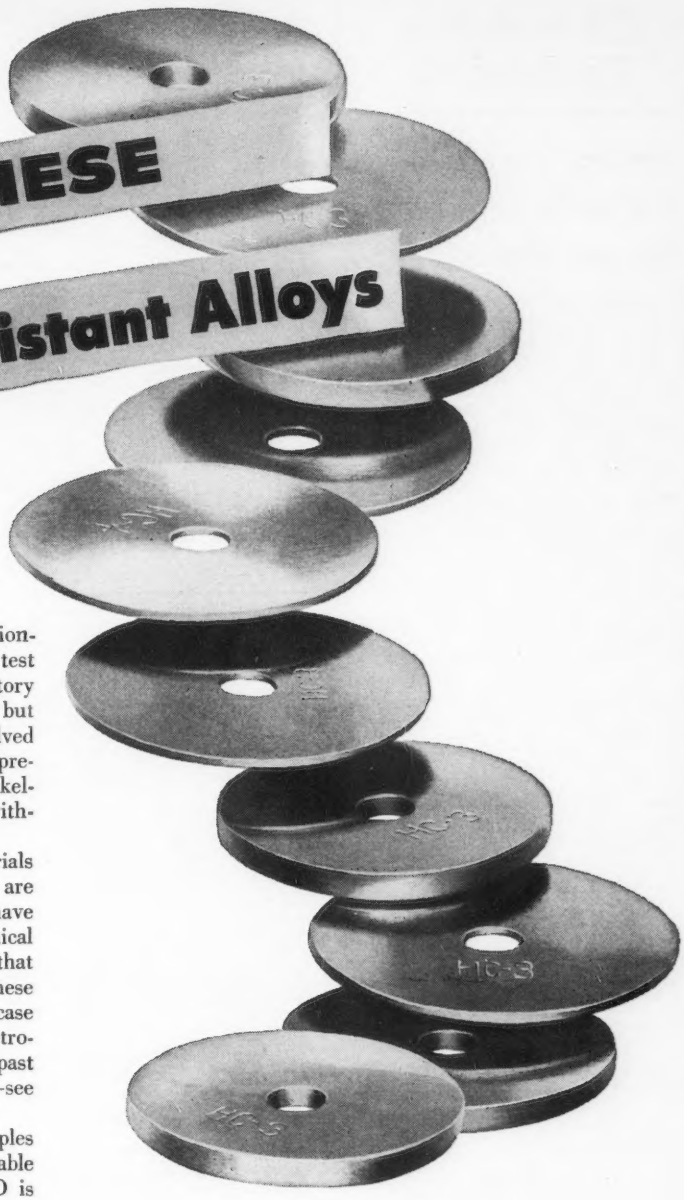

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Oil and Gas Production

Plastics, Offshore Structures, Laboratory Work on Agenda

Five papers to be presented during the Oil and Gas Production Symposium scheduled Tuesday, March 8, the second day of the 1955 Annual NACE Conference in Chicago will cover a wide variety of subjects pertaining to corrosion control in the oil and gas industry. Edward C. Greco, United Gas Corp. and W. E. Oxford, Jr., Sun Oil Co. are chairman and vice-chairman respectively.

Subjects will range from convenient methods for obtaining relative creep strength data for plastic samples in form of flat strips or rings cut from pipe to the control of corrosion on offshore drilling. Covered also are consideration of creep characteristics of thermosetting and thermoplastic materials and a description of laboratory work related to cathodic protection of oil well casing.

Abstract

Corrosion Control On Offshore Drilling and Producing Equipment. Charles J. Fritts

Experiences of a major oil company in control of corrosion on offshore oil drilling and producing equipment are discussed. Corrosion has been shown to be particularly severe in so-called "splash zone" of steel platforms and majority of investigative efforts at present time are directed toward finding most economical method of protecting this zone. Cathodic protection has proved to be economical means for preventing corrosion of submerged areas and data are presented to show its relative effectiveness. Cold-applied vinyl coating systems have proved to be superior for protection of atmospheric zone while hot-applied vinyl coatings and Epon coatings under test for this service are not yet thoroughly proved.

Author is of opinion that proper application of known materials and methods, combined with an adequate maintenance program will cause offshore equipment to last as long as necessary.

Abstract

Cathodic Protection Of Oil Well Casings. By Jack P. Barrett.

ABSTRACT
WITHDRAWN

Abstract

Effect of Water On Strength of Structural Plastics. By W. H. Sharp and M. K. Weber.

Plastic materials, including those reinforced with glass fibers are appreciably weakened by exposure to water. Full effect of water on strength is revealed by creep measurements under applied load in water at temperature of interest. Measurements are much more significant than those obtained by usual method of short term immersion followed by rapid ultimate strength tests in air. Convenient methods for obtaining relative creep strength data for samples in form of flat strips or rings cut from pipe are described.

Creep strength reduction extent of glass reinforced plastics in warm water appears to depend primarily on properties of resin, nature of glass-resin bond and temperatures and duration of exposure. Indications on range of strengths for reinforced plastics obtainable by changes of variables which control properties of resin and glass-resin bond are given, and comparison of wet creep strength for glass-reinforced plastics with ultimate strengths measured by rapid tests in air is made.

FRITTS

THORNTON

BRADLEY

CALDWELL

LYTLE

SHARP

WEBER

Abstract

Use of Structural Plastics In Oil Production. By B. W. Bradley and W. M. Thornton.

Data on approximately 100 oil field installations of plastic pipe, tubing and tankage studied by NACE Unit Committee T-1J on Oil Field Structural Plastics indicate that the relatively high failure frequency of these products is due almost entirely to physical rather than chemical properties.

Both thermosetting and thermoplastic materials, when stressed above a certain level, will "creep" until failure occurs, according to laboratory studies reported to the committee. This failure may occur in a matter of minutes or after several months, depending on stress level and specific plastic formulation. Short term tests to determine ultimate strength of structural plastics yield data of questionable value because of this behavior. That short term test data are in any way related to actual performance of structural plastics has not yet been shown. Under these conditions, such data can be misleading and literal application can be damaging to the reputation of the structural plastics industry.

In view of findings two suppliers of thermoplastic resins have developed and reported long-term strength data on their products which serve to verify early findings of the committee and emphasize necessity for additional studies of this nature.

ABOUT THE AUTHORS

CHARLES J. FRITTS—Sales representative of the Houston and South Texas areas for Socony Paint Products Company. He received a BS in industrial chemistry from the University of Kentucky in 1947. Prior to that he was employed by the Formica Insulation Company in the control laboratory and by Joseph E. Seagram & Sons in operations. After graduation he was for two years in research on the chemistry of drilling muds for the Field Research Laboratories of Magnolia Petroleum Company. Since 1949 Mr. Fritts has been concerned with all phases of corrosion control and from 1952-1954 was corrosion engineer on the Magnolia-Continental-Newmont operations at Morgan City, Louisiana. He is a member of NACE Unit Committee T-2E on Internal Corrosion of Product Pipe Lines and Tanks and Unit Committee T-6E on Protective Coatings for Petroleum Production.

W. M. THORNTON—Chemical engineer with the Atlantic Refining Company, Dallas. He holds a BS in chemical engineering from Texas Technological College. Since 1949 Mr. Thornton has been engaged in material application and corrosion studies for Atlantic's Domestic Crude Oil Production Department. He currently is chairman of NACE Unit Committee T-1J on Oil Field Structural Plastics.

B. W. BRADLEY—Employed by Shell Oil Company. He is principally concerned with corrosion and water treating problems in oil and gas production. Mr. Bradley received a BS in chemical engineering from Rice Institute in 1944 and a MA in business administration from the University of Texas Business School in 1949. He presently is vice chairman of NACE Unit Committee T-1J on Oil Field Structural Plastics.

J. A. CALDWELL—Senior research engineer for Humble Oil and Refining Company, Houston. He received a BA in mathematics from Henderson State Teachers College, Arkadelphia, Ark. and a MS in physics from Louisiana State University, Baton Rouge. Mr. Caldwell has worked on corrosion problems since 1945. A member of NACE since 1946, he is chairman of Unit Committee T-1D on Sour Oil Well Corrosion and a member of several other NACE technical committees.

MELBA LEE LYTLE—Research engineer for Humble Oil and Refining Company, Houston. She has been engaged in development and screening of inhibitors in sour-crude wells and corrosion by anaerobic bacteria. Mrs. Lytle received a BA (1933) and MA (1935) from Rice Institute. She has been a member of NACE since 1953.

W. H. SHARP—Chemist in the Materials Engineering and Corrosion Department of the Emeryville Research Center of Shell Development Company since 1951. He has been with the firm since 1945 prior to which he was engaged in engineering research at the University of California where he received a BS in chemistry and MS in mechanical engineering.

M. K. WEBER—Chemist in the Materials Engineering and Corrosion Department of Shell Development Company. He received a BS (1934) in chemical engineering and a MS (1936) in chemistry from Washington State College. Since 1944 Mr. Weber has been engaged in research and development work on non-metallic materials for petroleum and chemical equipment.

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Chemical Industry

Inhibitors, Mercury Corrosion, Valve Stem Pitting Are Topics

Seven papers to be presented in the Chemical Industry Symposium which is scheduled on Wednesday, March 9, the third day of the 11th Annual NACE Conference in Chicago have been divided into two sessions. They will deal with a wide variety of subjects pertaining to corrosion control in the chemical industry. W. B. DeLong, E. I. du Pont de Nemours & Co. and J. J. Heger, U. S. Steel Corp., are chairman and vice-chairman respectively.

Subjects range from a discussion of the pertchnetate ion as an inhibitor of corrosion of iron and steel to explanation of a radiochemical investigation of the role of mercury in corrosion of aluminum. Valve stem pitting, building design and corrosion testing of aluminum also will be covered.

Abstract

Corrosion By Valve Packing. By L. H. Rasmussen.

Result of observations in investigation of valve stem pitting during storage after hydrostatic testing was that presence of soluble corrosive agents in asbestos braid and graphite lubricant were responsible for condition. Various packing treatments, graphites, sacrificial elements and inhibitors were formulated or chosen and tests conducted at three locations using Type 416 stem material. Test results indicate removal of soluble corrosive constituents, incorporation of inhibitors or sacrifical elements and careful selection of graphite dry lubricant in packing manufacture are beneficial and necessary.

Abstract

The Design of Buildings for Corrosive Conditions. By C. H. Topping.

Industrial buildings are subject to many types of corrosive conditions and some conditions which though not corrosive in the true sense are so closely related that they are included for benefit of those who must design buildings to meet them. Methods of construction and protection for increased resistance are discussed. Building components covered are foundation, structiiral frame, roof deck and roofing, walls, floors, doors and windows. In most instances, costly or extraordinary precautions are not required. Important thing is usually a matter of correct design to withstand particular conditions involved. Right and wrong methods were illustrated.

Abstract

Corrosion of Stainless Steel In Ferric Chloride Solution. By Herman A. Liebhafsky and Arthur E. Newkirk.

Rapid corrosion occurs through pitting when annealed Type 302 stainless steel sheets are suspended in ferric chloride solution. Dissolution of sample can approach completion with unexpectedly little alteration in appearance of surface. Rate of weight loss with different samples is surprisingly similar with the four zones distinguishable in the usual case being: 1) a short induction period, 2) fairly constant, slow rate, changing slowly into 3) rapid rate and finally (when less than 2 percent of the sample remains) into 4) negligible rate.

Distinct rate zones do not exist if one side of the stainless steel plate is covered with a thin film of evaporated gold when corrosion is rapid at the outset but decreases gradually.

Induction-period experiments done with aid of a microbalance show that corrosion begins within one minute after a clean dry coupon is immersed in ferric chloride solution. That measurements of corrosion rate in this system are relatively reproducible has been demonstrated. Extension of measurements should yield valuable fundamental information about this corrosion process.

(Continued on Page 95)

RASMUSSEN

TOPPING

LIEBHAFSKY

NEWKIRK

CARTLEDGE

PLUMB

PHILIBERT

TWISS

GUTENPLAN

ABOUT THE AUTHORS

L. M. RASMUSSEN—Chemical engineer with Manning, Maxwell & Moore, Inc., Stratford, Conn., has been engaged in various phases of corrosion work since 1934. Following graduation from Pratt Institute in 1929, he spent several years in industry as a metal finishing engineer. For a number of years he was associated with both the late Dr. Colin G. Fink and Dr. C. L. Mantell, consulting engineers in corrosion and electrometallurgical research. His present work is in the control and prevention of corrosion of valves and instruments in the chemical and power industries. A member of NACE, he presently is secretary-treasurer of the Southern New England Section.

CHARLES H. TOPPING—Senior architectural and civil consultant of the Engineering Department, E. I. Du Pont Company. He received a BS in civil engineering from the Massachusetts Institute of Technology in 1928. His first job after graduation was a survey into Venezuela in connection with development of the Maracaibo oil fields. This was followed by design and construction work on water works and marine terminals in New York. In 1932 he was division engineer and later superintendent of construction for South Persia State Railways followed by an assignment with the University of Pennsylvania Archaeological Expedition to Persia where he was in charge of surveys and mapping. From 1935-1936 he was engaged in design and construction of a marine terminal at Albany, N. Y. He also was engaged as designer on refinery structures in Texas and supervised design and construction of water production facilities in Houston as well as directing design on industrial and ordnance construction in that area. Mr. Topping joined the Du Pont Company in 1942 as a civil engineer in the Design Division and in 1954 was named to his present position.

H. A. LIEBHAFSKY—Manager, Physical Chemistry Section, General Electric Research Laboratory, Schenectedy, N. Y. He received a PhD in chemistry from the University of California in 1929 and served as instructor until 1934 when he joined General Electric. His interests and publications include corrosion and surface phenomena, photoelectric spectrophotometry and x-ray absorption methods in chemical analysis and kinetics of reactions in solution.

A. E. NEWKIRK—Research associate, Physical Chemistry Section, General Electric Research Laboratory, Schenectedy, N. Y. He received a PhD in chemistry from Cornell University in 1940. After employment for two years with the Pigments Department of the Du Pont Company he joined the staff of the General Electric Research Laboratory where his interests and publications include the chemistry of boron, organic fluorine compounds and laboratory design.

G. H. CARTLEDGE—Engaged in fundamental research in the Chemistry Division of the Oak Ridge National Laboratory. He received a AB and AM from Davidson College in 1911, and a ScD in chemistry from the University of Chicago in 1916. From 1920-1931 he was associate professor, professor and director of college work in chemistry at Johns Hopkins University. Dr. Cartledge was head of the department of chemistry at the University of Buffalo 1931-1945 and dean of faculty and professor of chemistry at King College, 1946-1951. He is the author of textbooks on inorganic and physical chemistry and research papers in the fields of complex problems and theoretical chemistry.

B. J. PHILIBERT—Mechanical engineer in the Central Engineering Department of Olin Mathieson Chemical Corporation in Baltimore. He is responsible for standards, specifications and corrosion service. Prior to joining his present firm he was with United States Industrial

(Continued on Page 96)

Inhibitors, Mercury—

(Continued From Page 94)

Abstract

The Pertechnetate Ion As An Inhibitor of the Corrosion of Iron and Steel. By G. H. Cartledge.

Theoretical consideration of possible mechanisms to account for action of inorganic corrosion inhibitors of the XO_4^{n-} type led to discovery that pertechnetate ion, TcO_4^-, inhibits corrosion of iron and carbon steels in aerated water at temperatures from 23 to 250 C, the highest temperature investigated.

Chemistry and nuclear properties of technetium make it very useful in studying inhibitory process. Thus, it has been shown that inhibition may be achieved without precipitating more than radiochemical traces of reaction products on metal and even this amount is shown to be most probably of secondary origin.

Exposures of two years have not been attended by a continuous increase in amount of precipitated technetium. It was found that even at 250 C, 5 ppm of technetium in distilled aerated water effectively inhibited attack on SAE 1010 steel.

Inhibition depends on maintenance of some minimum concentration of dissolved pertechnetate, the amount being dependent upon nature of metal and its surface activity. Evidence points to a weak, reversible adsorption of inhibitor ion as source of inhibition. Perrhenate ion, ReO_4^-, is very similar to pertechnetate ion in geometry and charge, yet was found to have no inhibitory properties under any of several conditions studied. Observations make it clear that inhibition arises from some intrinsic property and it is tentatively suggested that this is a degree of internal polarity sufficient to induce a short-range electrostatic polarization at interface, whereby activation energy for cathodic part of corrosion process is increased.

Abstract

A Radiochemical Investigation Of The Role of Mercury In The Corrosion of Aluminum. By R. C. Plumb, M. H. Brown and J. E. Lewis.

Radioactive tracer technique has proved extremely useful in studying the role of mercury in corrosion of aluminum. By counting measurements it permits quantitative, non-destructive assays of mercury picked up by a surface. Distribution of radioactive mercury on corroded surface may be determined readily autoradiographically. Influence of pH, mercury concentration, quality of protective oxide film, length of time exposed to corrosive media and applied voltage on specimen was investigated. Conclusions are drawn as to mechanism by which mercury affects corrosion of aluminum. Methods for cleaning mercury from corroded aluminum are evaluated and new technique for removing mercury contamination described.

Abstract

A Practical Corrosion Service Program. By B. J. Philibert.

A corrosion engineer's work is both corrective and preventive. Doing better preventive work lessens corrective work required. A wide knowledge of materials and fabrication with good specifications to cover both is required of the corrosion engineer. Frequently a corrective corrosion or metals problem is the heart of an engineering problem. When a specific problem is isolated, the engineering problem usually must be solved before the materials problem. A simple substitution of materials of construction frequently is inadequate. By the accumulation and distribution of helpful preventive information, the corrosion engineer establishes his value as a consultant and recognition of his worth follows. Effective work by a corrosion engineer can save his company ten times or more his salary per year.

Abstract

Corrosion Testing of Aluminum. I. High Velocity Test Method In Aqueous Solutions. By Sumner B. Twiss and Jack D. Guttenplan.

Technique of corrosion testing, involving spinning of aluminum disks in aqueous solutions at high velocities, was used to investigate effect of various natural waters and antifreezes on aluminum corrosion. Type of aluminum used was XA-30 (Alclad), having zinc-aluminum cladding on one side and silicon-aluminum cladding on the other. It was established that increase in velocity of movement up to a maximum peripheral velocity of 4700 feet per minute (12,000 rpm) is accompanied by a systematic increase in corrosion rate reaching very high values in some water. Type of corrosion occurring at higher velocities is similar to that occurring at in-service low velocities. Aqueous solutions particularly corrosive to XA-30 were those combining high chloride ion concentration and high alkalinity (as OH^- or $CO_3^=$ ion), such as Royal Oak, Michigan, tap water. High alkalinity, up to pH 11, appears to cause severe attack of aluminum even in absence of chloride ion.

In permanent antifreeze solutions, Royal Oak tap water—ethylene glycol (1:1), effect of increase in velocity appeared to reduce an induction period that occurs before rapid corrosive attack sets in. In Royal Oak tap water—isopropyl alcohol solutions, velocity had no effect, corrosion remaining low at all velocities for 200-hour test. Ethylene glycol appeared to

(Continued on Page 96)

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Power and Communications

Instruments, Cables Galvanic Couples Covered in Program

Four papers dealing with subjects pertaining to corrosion control and testing will be presented by as many authors with wide experience in corrosion work in the power and communications industries during the Power and Communications Symposium scheduled Wednesday, March 9, the third day of the 11th Annual NACE Conference in Chicago. L. O. McCormick, Consolidated Gas, Electric Light & Power Company of Baltimore, and T. J. Maitland, American Telephone and Telegraph Co., are chairman and vice-chairman respectively.

Abstract

The Use of Half Cells for Field Corrosion Testing. By Robert Pope.
Number of tests conducted to demonstrate use of lead-lead chloride half cells for field corrosion testing on lead sheathed underground cables are discussed. Some of these compare results obtained using half cells with those obtained using plain lead earth electrodes. Others compare results obtained in area considered corrosive with those in area believed free from corrosion.

Summary of investigations to determine reproducibility of results is presented together with discussion of tests to help interpret lateral IR drops in the earth.

Abstract

Corrosion On the Florida Keys. By R. W. Ackermann and J. P. McArdle.
Corrosion control features for a long distance telephone cable linking city of Key West with Florida mainland are outlined. Cable consists of sections of aerial, underground in conduit, buried and submarine type construction and traverses approximately 40 ocean islands for 110 miles involved.

Corrosion control problems are characterized by unusual geographical conditions, multitudinous galvanic couples caused by heterogeneous metals, extreme variations in earth resistivity and close proximity of a paralleling cathodically protected pipe line.

Corrosion mitigation measures utilized consist of insulating joints in telephone cable sheath at 37 locations, magnesium anodes with current limiting resistors to provide varying degrees of cathodic protection at 57 locations, bonds between cable sheath and pipe line at 7 locations and other associated items.

Influencing factors and control features for one localized situation which is typical of problems encountered is outlined in detail.

Abstract

Atmospheric Galvanic Couple Corrosion. By K. G. Compton, A. Mendizza and W. W. Bradley.
Tests designed to provide fundamental information explaining behavior of galvanic couples in atmosphere with purpose to permit prediction of probable relative behavior are reported. Measurements of weight losses of couples in marine, industrial and severe tropical atmospheres also are reported.

Tests involving thin sheet electrode material separated by filter paper saturated with electrolytes are noted. Materials include aluminum, magnesium, stainless steel, copper, cadmium, zinc, nickel, tin chromium, lead electroplate, silver, low carbon steel and others. Potential measurements and weight loss data are given. Specimens exposed to atmospheres show several apparent weight loss anomalies.

Measurements of corrosion currents described provide quick means for determining probable relative corrosion behavior of couples and differences between couples "exposed" and "sheltered" are noted. Quantitative data provided are intended to be useful to design engineers.

Abstract

Carbon Anode Installed In Electric Cable Conduit, By Howard L. Davis, Jr.
A high ampere-year impressed current anode consisting of graphite rods connected to an insulated header wire has been developed and installed by Philadelphia Electric Company in its underground conduit system. Rods are 2 inches in diameter and 18 inches long and spaced 5 feet apart and pulled into a duct in lengths up to 500 feet. Special reels with flat sides are used to handle anode. Direct current is supplied to anode by one rectifier located in middle of conduit run. First installation was in 6000 feet of conduit to protect lead sheathed power cables. Tests indicate protection obtained is comparable to that available with continuous metal ribbon anodes but life expectancy is considerably longer and troubles of anode separation caused by uneven dissipation of ribbon type anodes is avoided.

POPE

DAVIS

ABOUT THE AUTHORS

ROBERT POPE—Retired in 1950 from Bell Telephone Laboratories where he had worked on developments and improvements in corrosion testing and preventive methods since 1934. He received a ME degree from Stevens Institute of Technology in 1920. Mr. Pope was employed by the Long Lines Engineering Department of American Telephone and Telegraph Company in charge of corrosion and electrical protection problems until 1924 when he was transferred to the company's Department of Development and Research. He was on the original NACE board of governors and is presently active on several NACE technical committees. Mr. Pope has presented several papers on various aspects of corrosion and contributed a chapter on Application of Cathodic Protection for the Corrosion Handbook.

HOWARD L. DAVIS, JR.—Transmission and distribution engineer, Philadelphia Electric Company. He received an electrical engineering degree in 1925 from Swarthmore College. Mr. Davis began corrosion mitigation work in 1927 on 66,000 volt underground cable system for his company and has devoted much time to corrosion on underground power facilities. He is chairman of a committee dealing with corrosion problems in all departments in his company.

ABOUT THE AUTHORS

(Continued From Page 94)

Chemicals for eight years. His earlier experience includes considerable work in the petroleum industry in Texas, Louisiana and Oklahoma. He is co-chairman of NACE Unit Committee T-5D on Plastic Materials of Construction, is on the executive committee of the Baltimore Chapter of the American Welding Society and a member of the American Society for Metals.

SUMNER B. TWISS—Head of the Physical-Chemical Department of the Engineering Research Section of Chrysler Corporation. He received a BS from Trinity College and a PhD from Johns Hopkins University, both in chemistry. Dr. Twiss was associated with the Finishes Division of the Du Pont Company and the chemistry faculty of Wayne University before joining Chrysler. His special fields of interest include synthesis and evaluation of resins and plastics, corrosion control, coatings, inhibitors and plating, surface chemistry, friction materials and friction phenomena and lubrication science.

JACK D. GUTTENPLAN—Project engineer in corrosion and electroplating research for Chrysler Corporation of Detroit. He received a BS in chemical engineering (1945) and a MS (1948) from Case Institute of Technology. Mr. Guttenplan investigated oil and gasoline inhibitors and protective coatings for Lubrizol Corporation and C. F. Prutton and Associates, Inc. until 1949 when he joined Chrysler. He has been actively associated with NACE since 1951.

ROBERT C. PLUMB—Research engineer, Radioactive Tracer Group, Aluminum Research Laboratories, Aluminum Company of America since 1952. From 1947-1949 he was research assistant for the Bersworth Chemical Company. Dr. Plumb holds a AB in chemistry (1949) from Clark University and a PhD (1953) from Brown University. His research interests include chelation chemistry, solid state physics, infrared spectra of crystals and tracer applications in metallurgy. He is the author of several technical articles.

Inhibitors, Mercury—

(Continued From Page 95)

accelerate corrosion and alcohols to reduce corrosion in all waters tested.

(This is the first of two papers on corrosion testing of aluminum.)

Abstract

Corrosion Testing of Aluminum. II. Development of A Corrosion Inhibitor. By Sumner B. Twiss and Jack D. Guttenplan.
An accelerated corrosion test is described with which a number of corrosion inhibitors were tested at different concentrations to determine effectiveness in preventing corrosion of XA-30 aluminum in Royal Oak, Michigan, tap water. Four inhibitors found to be effective under conditions of static test were 1000 rpm and 12,000 rpm soluble oil, with or without trisodium phosphate. All but the soluble oil are either non-compatible or might lose effectiveness when used in standard antifreeze solutions. Corrosion inhibition of clad aluminum by soluble oil is less effective in waters of combined high pH and high chloride ion than in waters of high chloride alone. Addition of buffer to soluble oil to maintain solution pH near 7.0 improves its effectiveness in high pH solutions. Combination of soluble oil and buffer satisfactorily inhibits corrosion of XA-30 in 1:1 ratio ethylene glycol—water (pH 11) and isopropyl alcohol—water (pH 11) solutions, typical of worst radiator solutions that might be encountered. Inhibition is less effective when clad aluminum is coupled with brass.

(This is the second of two papers on corrosion testing of aluminum.)

Abstract

A Radiochemical Investigation of the Role of Mercury in the Corrosion of Aluminum. By R. C. Plumb, M. H. Brown and J. E. Lewis.
Radioactive tracer technique has proved extremely useful in studying the role of mercury in corrosion of aluminum. By counting measurements it permits quantitative, non-destructive assays of mercury picked up by a surface. Distribution of radioactive mercury on corroded surface may be determined readily autoradiographically. Influence of pH, mercury concentration, quality of protective oxide film, length of time exposed to corrosive media and applied voltage on specimen was investigated. Conclusions are drawn as to mechanism by which mercury affects corrosion of aluminum. Methods for cleaning mercury from corroded aluminum are evaluated and new technique for removing mercury contamination described.

AWS Show Scheduled

The American Welding Society has scheduled its third annual Welding Show at the Municipal Auditorium in Kansas City, Mo., June 8-10, 1955.

Kushnik Heads ISA

William H. Kushnik has been appointed executive director of the Instrument Society of America which is scheduled to hold its 10th Annual Conference and Exhibit in Los Angeles on September 12-16.

Cathodic Protection

Measurements and Data Assimilation Are Two of Topics

Besides surveying measurements of major interest in cathodic protection the three papers to be presented in the Cathodic Protection Symposium include data on a novel method of assimilating information about a large network system adaptable to large or small companies and generalizations which seem to have some support for establishing effectiveness of protective currents on bare pipe. Symposium is scheduled for Thursday, March 10, the fourth day of the 1955 NACE Conference in Chicago. Francis W. Ringer, consulting engineer of Narberth, Pa., and John C. Howell, Public Service Electric & Gas Co., Maplewood, N. J., are chairman and vice-chairman respectively.

Abstract

Organization and Instrumentation of a Corrosive Control Group in a Gas Distribution Company. By James W. McAmis.

Organizational set-up and duties of a Distribution Utility Corrosion Group is touched on. Novel method of assimilating information about large network systems for later utilization in number of different ways is adaptable to large or small company. Method of applying previous experience to current installations is interesting process designed to reduce manpower requirements in Corrosion Control Group. Basic requirement of instruments to provide adequate testing of network and some problems peculiar to distribution work with suggested solutions are discussed.

Abstract

A Study of Protective Criteria on a Pipe Section in a Uniform Environment. By L. P. Sudrabin.

Importance of reference electrode location upon meaning of pipe-to-reference electrode potential measured is demonstrated by use of a model pipe section. Known anodic areas of high purity zinc were established on steel pipe and coupled through a milliameter. Potential gradient of coupled one-inch diameter zinc anode-pipe cathode system was not discernible by water surface potential measurement.

Generalizations for establishing effectiveness of protective current on bare pipe which seem to have support are: A) long line corrosion currents are controlled when protective potential (—.85 volts) is measured to a Cu-$CuSo_4$ reference electrode in remote location (more than 100 feet away from pipeline). Intermediate and local cell corrosion currents are reduced; B) long line and intermediate corrosion currents are controlled when protective potential is measured to a reference electrode placed over the pipeline. Local cell corrosion currents are reduced, and C) long line, intermediate and local cell corrosion currents are controlled when protective potential is measured close to pipe surface. Measurements A and B are critical to stray current, shielding and anode potential gradient effects. Measurements A, B and C tend to approach one another in low resistivity environments and/or when pipeline has resistive coating and/or where protective current requirements are low.

An equation is developed to calculate pipe surface potentials when potential to a reference electrode on ground surface over pipeline is determined.

Abstract

Instrumentation For Cathodic Protection. By H. N. Hayward.

Measurements of major interest in cathodic protection include those of voltage and current, pH, soil resistivity and coating conductance or performance. Attention is directed to instruments and methods rather than applications in the belief that better use will result if principles of operation and limitations of instruments are understood.

Principal emphasis is placed on electrical indicating instruments because of widespread and general use. Subjects covered include basic design and constructional features, theoretical and practical considerations of operation, sensitivity and accuracy, damping, power requirements and other factors associated with ruggedness or lack of it. Some special problems relating to recorders are considered and interrelated effects of instruments and circuits in making voltage and current measurements are discussed and methods are suggested for determining and correcting for these effects.

Theory, construction and operation of potentiometers and other null or zero loss instruments for voltage or current measurements are described. Vacuum tube instruments are considered briefly. Electrical determination of pH which requires measurement of voltage under special conditions is included along with brief description of instruments and electrodes used.

Measurement of soil resistivity presents some special problems which are outlined in connection with description of instruments and methods used for making measurements. Other specialized procedures and instruments described are those involved in making coating conductance measurements.

Abstract

(Title Unavailable.) By D. F. Van de Water.

Deals with cathodic protection of certain bare steel lines whose location preciuded reconditioning and coating. Proximity of other pipe lines made control of interference currents mandatory. Design, installation costs and operating costs for several such installations are presented as well as method used for determination of protection.

McAMIS

SUDRABIN

HAYWARD

VAN DE WATER

ABOUT THE AUTHORS

JAMES W. McAMIS—Staff engineer for the Street Department of Washington Gas Light Company. Since joining the company in 1935 as clerk he has worked in various engineering jobs including Utilization-Appliance Testing Laboratory and Customer-Appliance Service Department. In his present position he is responsible for corrosion control practices and procedures for his firm. Mr. McAmis received a AB in chemistry from Tusculum College in 1932. He has been a member of NACE since 1952.

L. P. SUDRABIN—Technical director of Electro Rust-Proofing Corporation, Newark, N. J. He graduated from Northeastern University, Boston, in 1936 with a BS in chemical engineering. Prior to joining Electro Rust-Proofing, Mr. Sudbury occupied the positions of research engineer with the Dorr Company, chief engineer with Dayton Power and Light Company and chemist with the Boston Edison Company. He has been a member of NACE since 1944 and is chairman of Unit Committee T-2C on Minimum Current Requirements for Cathodic Protection as well as being a member of several other NACE technical committees.

H. N. HAYWARD—Professor of Electrical Engineering at the University of Illinois. He has been interested in and concerned with instruments and measurements almost continuously since he joined the university faculty in 1929 and has been director of the Measurement Program in the Engineering Experiment Station since it was established in 1948. Although he still does some teaching, his major responsibility is with the instrument checking, maintenance and construction services and consultation facilities on instrument and measurement problems that have been set up to serve the university. He received degrees of BS and MS in electrical engineering and professional EE from the University of Illinois. Mr. Hayward is chairman of NACE Unit Committee T-3D on Instruments for Measuring Corrosion.

D. F. VAN DE WATER—Assistant chief engineer with Products Line Division of Sun Pipe Line Company. He started work with the Susquehanna Pipe Line Company, successor to Sun, in 1934 and since that time has been associatd with control or corrosion. He received his education at the U. S. Naval Academy and Rensselaer Polytechnic Institute. Mr. Van de Water has been a member of NACE since 1946.

Technical Council Named

The American Welding Society announces formation of a technical council to plan, review and coordinate all technical activities of the society.

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High Purity Water

Engineering, Materials Problems in High Purity Water Surveyed

Corrosion of structural materials and types of corrosion in high purity water as well as information regarding the activities and objectives of NACE Unit Committee T-3F on Corrosion By High Purity Water will be described in four papers to be presented in the High Purity Water Symposium which is scheduled for Thursday, March 10, the fourth day of the 1955 NACE Conference in Chicago. D. J. DePaul, Westinghouse Electric Corp. and A. H. Roebuck, Argonne National Laboratory, are chairman and vice-chairman respectively.

Abstract

Symposium On Corrosion By High-Purity Water, Introduction. By John F. Eckel.
Information is provided regarding activities and objectives of NACE Unit Committee T-3F on Corrosion By High Purity Water which was organized at 1953 meeting of NACE in Kansas City and gives brief description of points to be covered by the three papers of symposium of high-purity water and relationship between these papers.

Abstract

Corrosion Engineering Problems In High Purity Water. By D. J. DePaul.
Some important corrosion problems encountered in systems exposed to recirculating high purity water with respect to engineering application of materials are described. Special attention is given to crevice, galvanic, intergranular and stress corrosion as a function of various materials studied.

Abstract

Corrosion Of Structural Material In High Purity Water. By A. H. Roebuck.
Atomic Energy Commission and related industries have sought materials for use in high-temperature water having high corrosion resistance which are necessary for reactor construction in order to minimize or prevent contamination and chance malfunction. Materials must exhibit high resistance in water at temperatures of 600 F and in some instances higher.

Materials of highest corrosion resistance include austenitic stainless steels, cobalt alloys, gold, platinum, titanium, zirconium and hafnium. Corrosion rates are in the order of 0.1 milligrams per square centimeter per month. Of above materials and classes, platinum, AISI Types 316 and 347 stainless steels, titanium and zirconium exhibited highest all around resistance.

Materials of intermediate corrosion resistance include aluminum and aluminum alloys, chromium, 70-30 copper-nickel, cobalt, ferritic and martensitic stainless steels, nickel and nickel alloys. Under proper conditions these may exhibit high corrosion resistance, although as a rule they do not possess overall resistance to attack shown by metals listed in first class and must be used with additional caution.

Materials of lowest resistance include copper, bronzes, magnesium, plain carbon steels and silver. Of these plain carbon steels merit special consideration and further study. Other materials in this group should not be used in systems of type under consideration without further evaluation.

Of factors affecting corrosion system temperature, system gas concentration (particularly with respect to dissolved oxygen) and metal surface conditions are of importance. Steels, nickel and nickel alloys and copper and copper alloys show highest resistance in systems having low oxygen concentrations.

Biographies and photographs of authors who also are officials are published on Pages 80-84 herein.

ECKEL

JOHN F. ECKEL—Materials engineer with the Knolls Atomic Power Laboratory, General Electric Company. He graduated from the University of Kansas in 1925 and received his DSc in metallurgical engineering from the Carnegie Institute of Technology in 1932. Prior to joining General Electric he was associate professor of Metallurgical Engineering at Purdue University. Dr. Eckel presently is vice-chairman of NACE Unit Committee T-3F on Corrosion by High Purity Water.

Construction of Nuclear Engine Brought Many Corrosion Problems

Engineers whose job it was to aid in selecting materials for the nuclear power plan for propulsion of a submarine faced the problem of combating wear in a corrosive environment of high temperature, high purity water. Parts such as anti-friction bearings, linear sliding guide bearings, latches, valve parts and actuators and even nuts and bolts all had to be designed to operate in this corrosive environment with water as the only lubricant to combat wear. Experiments to find suitable combinations of materials for bearings operating in 500 F water were carried on by engineers of Westinghouse Electric Corporation Atomic Power Division, Bettis Field, P. O. Box 1468, Pittsburgh 30, Pa. A paper giving findings of the search was written by R. C. Westphal and J. Glatter.*

Corrosion being a known major factor from the beginning, engineers first selected 18-8 type stainless steels for much of the assemblies. "However," the authors state, "it was soon discovered that even the very simplest mechanical parts would gall and seize when assembly was attempted, or at best, after a very few cycles of operation. This condition was found to be so severe that it prevented the successful use of 18-8 stainless steel nuts and bolts larger than 0.5-inch in diameter." The importance of corrosion in wear was later borne out by experiments in which a partial pressure hydrogen was substituted for a partial pressure of oxygen-argon mixture.

Wear Factors Analyzed

Various causes of wear listed were: Abrasion, cutting, welding followed by shear, plastic deformation, fatigue cracking and corrosion. Five influencing factors to be considered for reducing wear were stated as: Environment, the medium in which the moving elements operate, such as temperature, pressure; geometry (including surface finish); load, relative surface velocity, materials. 2nd service conditions, that is, whether continuous or intermittent operation is involved.

Objectives of the simulated wear test program were two-fold. The primary objective was to evaluate the wearing propetries of as many materials combinations as possible under expected operating conditons. The secondary objective was to learn as much as possible concerning the other five influencing factors.

To simulate conditions, water was heated to 500° F, with 500,000 ohm-cm minimum resistivity and containing between 2 and 25 cc per liter of dissolved oxygen. A number of commercially available stirring-type stainless steel autoclaves were set up so that mechanical motion could be introduced into the high pressure space. Sigma grade argon gas (95 percent argon, 5 percent oxygen mixture), was used to maintain the desired oxygen content in the water. To obtain the proper oxygen concentration, the gas was brought to a pressure of 100 psi above saturated steam pressure or a total of 765 psi.

Two types of tests were chosen as being representative of the sliding motions expected in service. One was a piston and cylinder combination involving pure linear motion. The other was a sleeve bearing and journal combination which gave rotary motion.

Weight Change Reproducible

In determining the amount of wear, dimensions were measured to 0.00001 inch; weights were measured to 0.1 mg and surface roughness measurements were made in microinches. Early weight test data showed that weight change was one of the most sensitive and most reproducible measures of wear. However, in a small number of cases, involving porous materials which absorbed water and soft materials which wiped or flowed under load, dimensional measurements were of greater significance. By taking all three measurements, it was found the test results could be described very well.

Duration of tests was approximately 500,000 cycles or revolutions. Standard piston-cylinder tests were conducted with the specimens under a 3-lb. radial load. The journal-sleeve bearing tests were performed with a load of 7.5 lb. Over 700 piston-cylinder tests and over 300 sleeve bearing tests were completed.

Wear Proportional to Cycles

Early tests further proved that the amount of wear was directly proportional to the number of cycles of operation. To evaluate the relative merit or performance of materials combinations, a wear factor was evolved. This factor has the units of milligrams weight loss per pound load, per million cycles.

Nitrided surfaces are best in wear resistance and anti-galling characteristics, but nitrided chromium and nitrided titanium are the only two materials in this group with sufficient corrosion resistant in water to be usable.

Second in wear resistance is hard industrial chromium plate. It was found it could be used successfully with a wide variety of mating materials. Corrosion resistance was assured by plating on a corrosion resistant base of stainless steel, since the porosity in the plate otherwise might cause eventual lifting of the plate. The danger of flaking and scuffing of chrome plate was minimized by proper control.

(Continued on Page 99)

Elevated Temperature

Corrosion by Molten Sodium, Lithium and Lead Is Discussed

Corrosion techniques developed to study corrosion of liquid metals will be explained as well as the effect of molten sodium sulfate on oxidation of Type 310 steel in two papers to be considered in the Elevated Temperature Symposium scheduled Thursday, March 10 during the 1955 NACE Conference in Chicago. E. N. Skinner, Jr., International Nickel Co. and C. C. Harvey, Ethyl Corp., are chairman and vice-chairman respectively.

That liquid metal corrosion has been found to be mainly a solution phenomenon is pointed out by one author.

Abstract

The Effect of Sodium Sulfate On The Oxidation of Alloy Steels At Elevated Temperatures. By Edward L. Simons, George V. Browning and Herman A. Liebhafsky.

Sodium sulfate is one of the ash constituents produced when residual fuels are burned in gas turbines. Under certain operating conditions this salt can lead to build-up of heavy deposits in the turbine which are undesirable from a mechanical and corrosion point of view. Field experience and supplementary laboratory examination have shown effects of temperature and sodium sulfate content on sintering behavior of turbine ashes and have defined conditions under which undesirable tightly adherent deposits can be formed.

Effect of molten sodium sulfate on oxidation rate of Type 310 steel has been studied in the laboratory. In absence of reducing conditions, either localized at metal surface or induced in environment, molten salt produces no appreciable oxidation increase rate. Rapid oxidation does occur when alloy sample coated with sodium sulfate is subjected to cycling reducing and oxidizing conditions at or above 800 C. Qualitative experiments have demonstrated effect of localized reducing conditions in triggering oxidation of alloy specimens immersed in molten sodium sulfate.

Undesirable mechanical and corrosion consequences caused by sodium sulfate in gas turbine deposits justify large scale and successful efforts by General Electric Gas Turbine Department to wash out sodium compounds from residual fuel before it is burned.

Abstract

Corrosion Of Materials In Sodium, Lithium and Lead. By W. D. Manly.

For the past several years liquid metals sodium, lithium, lead and bismuth have been examined for possible use as heat transfer media in various Atomic Energy programs. Corrosion techniques and equipment have been developed to study corrosion by these coolants and it has been found that liquid metal corrosion is mainly a solution phenomenon. Effect of impurities, temperature, temperature gradient and flow velocity on corrosion mechanism has been examined and is presented. Temperature gradient mass transfer and isothermal mass transfer (dissimilar metal transfer) are discussed.

Investigations reveal sodium to be compatible with most alloys of construction of cobalt-base, nickel-base or iron-base type. Lithium and lead are more difficult to contain and only materials such as pure iron, iron-base alloys, 400 series stainless steels, molybdenum, tungsten, columbium and tantalum show much promise as containers. In these environments austenitic stainless steels and nickel-base alloys are severely corroded.

ABOUT THE AUTHORS

EDWARD L. SIMONS—Research associate, Analytical Chemistry Unit, General Electric Research Laboratory, Schenectady, N. Y. He received a PhD in chemistry from New York University in 1945. After two years on the Manhattan Project Dr. Simons served for five years as assistant professor at Rutgers University. His interests include inorganic analysis, phase equilibria and corrosion phenomena. He is a member of NACE Unit Committee T-3B on Identification of Corrosion Products.

SIMONS

BROWNING

MANLY

GEORGE V. BROWNING—Supervisor, Physical Chemistry Unit, Materials and Processes Laboratory, Large Steam Turbine and Generator Department, General Electric Company. He received a PhD in chemistry from the University of Wisconsin in 1948 and worked for the Polymer Corporation of Ontario and Standard Oil of Indiana prior to joining General Electric in 1951. Dr. Browning's interests include lubrication, electrochemical and corrosion problems.

W. D. MANLY—Metallurgist at the Oak Ridge National Laboratory where he is engaged in research on high temperature materials problems as applied in Atomic Energy work. He received a BS and MS in metallurgy from the University of Notre Dame and presently is taking courses at the University of Tennessee for his PhD. Mr. Manly is a member of NACE Unit Committee T-5B on Materials for Use at High Temperatures. He also is a member of the American Institute of Mining and Metallurgical Engineers and the American Society for Metals and was chairman of the Oak Ridge Society for Metals 1953-1954.

Nuclear Engine–

(Continued From Page 98)

Other Materials Rated

Excellent wear resistance was found with straight chrome stainless steels as compared with nickel-chrome stainless grades, but the former were unacceptable for use in oxygenated water because of pitting corrosion. The only sintered carbide found acceptable with respect to corrosion considerations was Carboloy No. 608 which is chromium carbide bonded with nickel. Another class of materials having low wear factors are Stellites, which are cobalt base alloys. An intermediate material, Metamic LT-1, a cermet consisting of chromium and alumina, exhibited excellent wear and corrosion resistance when run in combination with an abrasive resistant mating material.

Hardness Influence Weighed

The tests revealed that hardness has a very pronounced, yet inconsistent effect on wear. Nitrided surfaces, chrome plate and Stellites have hardnesses in decreasing values which correspond to decreasing wear resistance. But Armco type 17-4 PH vs. Stellite No. 3 (R_c 54-60) has a wear factor almost three times greater than Armco type 17-4 PH vs. Stellite No. 6 (R_c 40-46).

Surface finish is an important variable. When the mating materials differ greatly in hardness, it is important that the harder of the two have a good finish; otherwise, wear is accelerated by continuous cutting action on the softer material or by loading of the rough surface followed by abrasive wear.

An appreciation of the effect of corrosion on wear was obtained by comparing the wear factors of materials in oxygenated versus hydrogenated water. Results of a number of tests, alike in every respects except that a partial pressure of hydrogen was substituted for the oxygen-argon mixture were examined. In almost every case a substantial reduction in wear factor is noted in hydrogenated water. The greatest change took place with those materials which are most susceptible to oxidation. Everdur No. 1012 (silicon bronze) vs. chrome plate, for example, has a very low wear factor (2.2) in hydrogenated water and an extremely high factor (830) in oxygenated water. Likewise, there was an 88 percent reducation in wear for the KR-Monel vs. chrome plate combinations. In contrast, the Stellite combinations, because they are more oxidation resistant, did not show improvements of this magnitude, their reductions ranging only from a few percent up to a maxium of 50 percent.

★ Summarized from a paper titled "Wear and Friction Properties of Materials Operated in High-Temperature Water," by R. C. Westphal and J. Glatter, Westinghouse Electric Corp., Pittsburgh. Presented at the Pittsburgh Semi-Annual Meeting, American Society of Mechanical Engineers, June 20-24, 1954. Paper based on a report dated December 4, 1953 of the same title prepared under the Naval Reactor Program.

How CORROSION Is Indexed

Annually, in December issue, a cross-referenced tabular topical index of the material published in the Technical Section is published. An alphabetical subject index was published in the December, 1954, issue.

Annually, in December issue, an alphabetical author index is published.

Annually, in December, a tabular index to the Corrosion Abstract Section is published.

Monthly, technical articles published in Corrosion are abstracted in the Corrosion Abstract Punch Card Service.

5 Year Index, 1945-49, consisting of a cross-referenced tabular topical index and an alphabetical author index was published in the December, 1950, issue of Corrosion.

Bibliographic Surveys of Corrosion—Corrosion Technical Material is indexed in the NACE's Bibliographic Surveys.

Corrosion is regularly indexed by Engineering Index.

10-year Index, 1945-54—In preparation and scheduled to appear early in 1955 is a 10-year index to the Technical Material published in Corrosion. It will consist of an alphabetical subject index and an alphabetical author index.

No indices of other sections of Corrosion are prepared by NACE.

All indexing is done, as far as practical, according to the NACE Abstract Filing System Index, which is used for NACE Abstract Punch Cards and the biennial Bibliographic Surveys of Corrosion.

Pipe Line General and Problem Clinic

Several Sessions to Be Devoted to Pipe Lines

Many aspects of pipeline corrosion will be considered during the Pipe Line Problem Clinic, Pipe Line and Underground Corrosion Roundtable and Pipe Line General Symposium which are scheduled to meet during the 1955 Annual NACE Conference in Chicago.

The Pipe Line Problem Clinic to be held Thursday, March 10, the fourth day of the conference will be divided into three groups led by as many experts in the field of corrosion mitigation. The Cathodic Protection Clinic will consider such subjects as production, gathering and distribution systems; oil, gas and products transmission lines; refineries, and oil and products storage tanks. Salt water (offshore structures, boats and barges), bare pipe lines (hot spot protection), instrumentation (cathodic protection surveys) and advanced methods of cathodic protection will also be discussed. Charles L. Woody, United Gas Corp., is discussion leader. The Internal Corrosion Clinic on Pipe Lines and Storage Tanks will deal with inhibitors, protective coatings and design and operation. Ivy M. Parker, Plantation Pipe Line Co., is discussion leader. The Protective Coatings Clinic on Pipe Lines will view on the line operations, yard application and cold applied coatings. L. A. Hugo, Phillips Petroleum Co., is discussion leader.

The Pipe Line and Underground Corrosion Roundtable, one of the most popular events on the technical program at NACE conferences will be held on Friday, March 11, the fifth day of the conference. It features free exchange of information which is unrehearsed, informal and unrecorded. J. P. Barrett, Stanolind Oil and Gas Co. and Loyd B. Nelson, Shell Pipe Line Corp. are chairman and vice-chairman respectively.

Internal plastic coatings and techniques for measuring electrical conductance of coating on buried pipelines are discussed in two papers to be presented in the Pipe Line General Symposium scheduled on Wednesday, March 9, the third day of the conference. While plastic coatings have proved successful and show definite payout an economic study should be made to determine most practical means of protection, one author says. The second paper discusses the Report on Proposed Standard Method for Measuring Electrical Conductance of Coating on Buried Pipe Lines by NACE Unit Committee T-2D on Standardization of Procedure for Measuring Pipe Coating Leakage Conductance with author's comments on items which probably will require further review. J. N. Hunter, Jr., Service Pipe Line Co., is chairman.

WATTS

HEVERLY

ABOUT THE AUTHORS

J. C. WATTS—Corrosion engineer for the West Texas Division of Humble Pipe Line Company. He received a degree in chemical engineering from Mississippi State College in 1944 and attended graduate school at the University of Alabama. He has been associated with Humble Pipe Line Co. as a corrosion enginer since 1948 and at present is chairman of NACE Unit Committee T-2F in Internal Sour Crude Corrosion of Pipe Lines and Tanks.

L. F. HEVERLY—Corrosion engineer for Buckeye Pipe Line Company. He holds a BS (1938) in electrical engineering from Pennsylvania State College. He started corrosion work in 1941 for Long Lines Plant Department of American Telephone and Telegraph Company and was a corrosion engineer for Ebasco Services, Inc. and chief corrosion engineer for Great Lakes Pipe Line Company. Mr. Heverly was first chairman of the Kansas City Section of NACE and is now serving as vice chairman of Unit Committee T-2D on Standardization of Procedures for Measuring Pipe Coating Leakage Conductance.

Abstract

Internal Plastic Coating of Pipe Lines In Place. By J. C. Watts.

Internal corrosion of pipe lines handling sour crude has been a serious problem in the West Texas area. As early as 1940 internal plastic coating of pipe lines was investigated using the only materials available, baked phenolics, which were not very practical for use in line pipe. Development of air dried vinyls widened use of plastic coating elsewhere but did not prove a practical means of protecting pipe lines already in place.

After 1948 when a method of internally coating pipe lines in place was developed tremendous strides were made in developing application techniques. Although many problems involved have been evaluated, much work still needs to be done. Improved cleaning methods make it possible to obtain better bond between coating and pipe and development of a high solids vinyl and epoxy type coating have provided coating materials designed especially for this service. A major problem is drying of applied coating film.

Experience reveals coatings applied in this manner show payout of one to five years, depending on length of line and severity of corrosion. Plastic coatings have proved successful and show definite payout but an economic study should be made to determine most practical means of protection. Generally the cheapest method of protection will be plastic coating in lines under five miles. For longer sections and when laying new pipe, in many cases, some other means of protection should be considered.

In addition to providing protection from internal corrosion, lines which were internally plastic coated have shown resistance to paraffin and scale deposition as well as increased capacity over uncoated lines. Although this method of protection was developed primarily for protection of lines handling sour crude, it has been used successfully in lines handling water, gas, gasoline and butane. Recently it has been used to coat lines in chemical plants.

Abstract

Discussion Of A Report On Proposed Standard Method For Measuring Electrical Conductance Of Coating On Buried Pipe Lines. By L. F. Heverly.

Report on Proposed Standard Method for Measuring Electrical Conductance of Coating on Buried Pipe Lines by NACE Unit Committee T-2D on Standardization of Procedures for Measuring Pipe Coating Leakage Conductance

(Continued on Page 101)

CLEANING, COATING, WRAPPING & RECONDITIONING

★

HOT DOPE

Straight from the Kettle on PIPE PROTECTION

★

By Boyd Mayes

Every so often I keep seeing in the paper that Congress may have to raise the legal debt limit so the government can keep operating. Seems to have gotten past the point of ever hoping or thinking about reducing the national debt. Brings to mind some fellows I've heard say they'd feel successful when they could owe a million dollars. At the rate we're going, looks like the national debt will have us all owing at least a million a piece before too many years. Looking at our debt that way—guess there ain't no question but that we've got the most successful government the world has ever seen—and gettin' more so every year. Personally, though, I'm mighty proud to live here no matter how successful we get.

And I'm mighty proud of another thing—that's the PERMANENCE we've been putting into pipe for well over a quarter of a century. We've got the plant, men and machines to do any size job for you—successfully.

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Protective Coatings

Variety of Topics to Be Covered on Coatings

Application techniques and resistant values of certain coatings, economy of a sound painting program and an investigation of shipbottom pitting are described in four papers to be presented in the Protective Coatings Symposium which is scheduled on Thursday, March 10, the fourth day of the 11th Annual NACE Conference in Chicago. W. B. Meyer, St. Louis Metallizing Co. and W. P. Cathcart, Tank Lining Corp., are chairman and vice-chairman respectively.

Abstract

Application Techniques and Resistant Values of Catalytically Cured Phenolic Resin Coatings. By F. J. Ploederl.

Various application techniques and chemical resistance properties of modified phenolic resin coatings polymerized by addition of a catalyst and effects produced by use of various modifying agents with results obtained using different catalysts are described. Accepted surface preparations for different materials such as steel, concrete and wood are fully described. Included are results obtained with use of a thin film of metallizing when applying phenolic coatings on steel and ferrous types of metals.

Use of film reinforcing materials such as glass cloth and asbestos and their effect on the ultimate life of various coating formulations are given. Typical field applications are listed covering use of coatings in paper mill, chemical and allied services.

Abstract

Organization and Administration of A-Plant Painting Program. By W. E. Chandler and William Sisler.

The management problem is to select and apply a combination of materials of construction and paints which yields best economic maintenance and replacement costs. Technical developments in the paint field have been very rapid and it is necessary for plant maintenance organizations to re-evaluate painting programs for optimum results because of this technical advancement.

A sound painting program must include: 1) assignment of sufficient engineering and managerial talent to the problem, 2) study of basic design with view to eliminating necessity of painting where possible and when required to minimize painting problems, 3) conducting engineering research studies of materials available in plant environments, to determine most suitable and 4) consideration of painting by systems rather than as application of a single material. After an adequate painting system is installed it must be maintained like any other program. It is logical that maintenance of the painting system include periodic inspections and follow-up. A continuing study of maintenance and replacement costs must be made to insure that best over-all economics are obtained.

In plants where painting programs exist without real engineering attention, development of a well-engineered program properly administered normally will lead to more adequate protection and a considerable cost reduction.

Abstract

The Investigation of An Unusual Cause of Shipbottom Pitting. By R. P. Devoluy.

An investigation of two cases of shipbottom pitting which occurred in polluted harbors 3000 miles apart but showed same symptoms of rapid pitting, inactivation of antifouling paint where it had turned black and good electrical conductivity of black surface film. Black conversion product found only in upper layer of antifouling paint was shorted to steel hull.

Study of painting history of vessels and in service conditions to which they were exposed indicated two common factors were present on the ships that pitted. These were contact between antifouling paint and steel hull and exposure to sulfide forming waters.

To confirm a theory about the cause of pitting a series of test panels duplicating conditions experienced in service were prepared. The tests, with suitable controls, tend to substantiate the theory and information so obtained makes possible recommendation of simple measures to prevent recurrence of this type of underwater corrosion.

PLOEDERL

CHANDLER

DEVOLUY

RADECKE

Abstract

Basic Essentials for The Reduction of Atmospheric Corrosion. By Frank Radecke.

Ravages of atmospheric corrosion cause extensive losses to industrial plants. Metal loss rates are in proportion to the severity of environment. The petroleum industry can be considered to have serious atmospheric corrosion problems because most steel structures and equipment in refineries are constantly attacked by crude-oil components and treating chemicals in forms of spills, leaks and atmospheric effluents and cooling water-tower condensate. Humid climate and waste materials used as fuels greatly increase surface-corrosion potential.

Most common method of protection is to apply coatings of paint on exterior steel surfaces. More important aspects of painting are types of surface preparation, paint selection based on environmental severity, number of coats to be applied and dry-film thickness. Best combination of these factors must be determined by the engineer to afford adequate protection within limits of economic practicability.

Shell Oil Company's engineers have established a number of basic coating practices and developed specification paints for use in refineries. Improved methods in the field in conjunction with specification materials have achieved satisfactory surface protection at reasonable cost.

ABOUT THE AUTHORS

F. J. PLOEDERL—In charge of coating research and development of the Wisconsin Protective Coating Company, Green Bay, Wis. He has 19 years of corrosion work, principally in the formulation and application of phenolic coatings for severe corrosion environments. He has been a member of NACE since 1948.

W. E. CHANDLER—Plant engineer of the Monsanto Chemical Company, he was graduated from Georgia School of Technology with BS in mechanical engineering in 1938. He spent two years in plant maintenance work at the Huntington, W. Virginia plant of American Car and Foundry and then one year at Purdue University where he received a MS in mechanical engineering in 1941. In 1945 he was employed as maintenance engineer at the Nitro, W. Virginia plant of Monsanto advancing in 1947 to superintendent of maintenance and construction and in 1951 to plant engineer. He was named to his present position in 1953.

R. P. DEVOLUY—National marine manager of the Glidden Company, New York City. He has been active in corrosion work since 1936. Mr. Devoluy specialized in corrosion while serving as assistant laboratory officer, Material Laboratory, New York Naval Shipyard from 1941-1945. A member of NACE since 1947, he presently is chairman of Unit Committee T-6C on Protective Coatings for Resistance to Atmospheric Corrosion. Mr. Devoluy received a BS and MS in chemical engineering from the College of the City of New York.

FRANK T. RADECKE—Head of the engineering standards development of Shell Oil Company. He is also chairman of the atmospheric corrosion committee of the manufacturing department of his company, which is primarily concerned with corrosion mitigation. A veteran of 42 years in petroleum engineering, he has served 21 of them with Shell.

General Corrosion Round Table Scheduled

The General Corrosion Roundtable will consider all problems of corrosion except those which deal with pipeline and underground corrosion. The meeting which is informal, unrehearsed and unrecorded will offer those attending the opportunity to ask questions which will be answered insofar as answers are available. One of the most popular events on the technical program at NACE conferences, the roundtable is scheduled for Friday, March 11, the fifth day of the 1955 NACE Conference in Chicago. A. O. Fisher, Monsanto Chemical Co. and F. N. Alquist, Dow Chemical Co., are chairman and vice-chairman respectively.

Cathodic Protection Is Growing in Britain

Evidence of increasing use of cathodic protection in Britain with reports received on approximately 200 installations either in operation or projected has led to the organization in that country of the Joint Committee for the Coordination of the Cathodic Protection of Buried Structures.

The committee is apparently intended to function in a manner similar to the Correlating Committee on Cathodic Protection, National Association of Corrosion Engineers, with the exception that it will be an operating group with some characteristics of electrolysis committees as they are organized in the United States.

The committee reports that because of ultimate necessity to make its findings generally available a technical panel has been set up to study cathodic protection with a view to eventual drafting of a code of practice with special reference to the possibility cathodically protected systems may endanger adjacent buried structures and to joint protection schemes.

Several Sessions—

(Continued From Page 100)

is discussed with author's comments on items which probably will need further review.

Technique for measuring electrical conductance of coating on buried pipe lines discussed in committee's report covers ΔI - ΔV approximate method and accuracy to be expected by comparing results with curves for particular size pipe line involved based on general case rigorous attenuation formulae.

Caution must be exercised always in adhering to procedures recommended in committee's report to keep errors in measurements and calculations to a minimum even though ΔI - ΔV method is simple to use. In this manner accurate measurements can be made and repeated by other interested persons, if desired, in deciding if new pipe line coatings meet requirements set forth in specifications.

Educational Lectures

Popular Educational Lectures to Be Given

Three papers will be presented in as many Educational Lectures scheduled during the 11th Annual NACE Conference in Chicago. The lectures were presented as an experiment during the 1953 NACE Conference in Chicago and their popularity then and at the 1954 Conference in Kansas City based on attendance has encouraged their inclusion in this year's conference schedule.

Subjects will range from characteristics of liquid metals used as coolants and heat transfer systems in power production and atomic energy work to the technique of handling a corrosion problem. V. V. Kendall, National Tube Division of U. S. Steel Corp., W. D. Manly, Oak Ridge National Laboratory, and H. N. Hayward, University of Illinois, are the lecturers.

Abstract

Fundamentals of Liquid Metal Corrosion. By W. D. Manly.

Interest in liquid metals as coolants and heat transfer systems in power production and atomic energy work has increased in the past few years with the result that intensified research to determine compatibility of various structural metals with these unique coolants has been undertaken.

Corrosion of structural metals in liquid metals is the result of the solubility of various metal or alloy constituents in liquid metal. Solution manifests itself by giving rise to many types of attack ranging from simple solution to deep intergranular with preferential leaching of one constituent of an alloy. Examples of many types of corrosion experienced with solid metal-liquid metal systems are illustrated and role of impurities in corrosion is discussed.

In addition to the solution stage, which would soon disappear in a static one metal system on reaching a solubility limit, corrosion of metals can be continued through removal of materials from solution in liquid metal with a temperature gradient or by dissimilar metal transfer. Compared to corrosion in static systems the transfer of metal from hot region of a plumbing system with deposition in a cold zone and transfer of material from one part of the system and its alloying with a metal of different composition in another part of the system is greatly increased.

Examples of temperature gradient mass transfer and dissimilar metal transfer are reviewed and factors governing occurrence of these phenomena are outlined.

Abstract

The Diagnosis of Corrosion Problems. By V. V. Kendall.

Technique of handling a corrosion problem from time it is received until final report is delineated is discussed. This involves furnishing proper questionnaire form to salesman or field engineer, development of essential information not furnished with original request for assistance, processing of specimen when received and preparation of final report. Ninety-five percent of information on any problem is contained in corroded specimen. Examples are given. Fundamental factors involved are correlated with problem in simple, readable form in final report. Corrosion engineer, if possible, should personally inspect installation. Sales angle associated with problem is discussed.

ABOUT THE AUTHORS

V. V. KENDALL—Corrosion engineer for the National Tube Company for over 30 years. He received an AB from Missouri Wesleyan College and a BS in education and a MA in chemistry from the University of Missouri. A member of NACE since 1944, he has been a member of Technical Practices Committee T-1 on Corrosion in Oil and Gas Well equipment, chairman of TP-8 on Corrosion by Waters, chairman of TP-10 on Corrosion Fatigue and chairman of the Pittsburgh Section 1950-1951. He presently is chairman of Unit Committee T-4E on Analysis of Domestic Waters. Mr. Kendall also is an active member of the American Society for Testing Materials, and American Iron and Steel Institute.

KENDALL

Van Antwerpen Is Named AIChE Secretary

F. J. Van Antewerpen has been elected secretary and appointed executive secretary of the American Institute of Chemical Engineers. He succeeds Stephen L. Tyler who is scheduled for retirement December 31. Earlier this year Mr. Van Antwerpen was named publisher for the institute's publications. He is replaced by John B. Mellecker as editor of Chemical Engineering Progress magazine.

•

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General News

Barbed Wire Fence Still Good After 75 Years on Farm

By E. A. TICE*

The sample of barbed wire, shown on the cover of this month's issue of Corrosion, was recently received from a 90 year old Iowa farmer, who recalls its installation on his family's farm during his boyhood 75 years ago. Although this was not suspected to be of some magic material having mystical corrosion resistance properties, a laboratory examination was undertaken to check its chemistry and the probable steel making practice employed in its manufacture.

The wire is of historical interest because it represents some of the early barbed wire made for farm fence use in this country. As can be noted the wire cross section is oval, or possibly rectangular, rather than round, and has been twisted about one turn every 5 inches. The barbs are two pointed, made from smaller sized wire, having probably been applied by hand.

One of the steel wire producers who has collected similar old wires, traces this particular barbed wire to patents issued in 1875 to J. Dobbs & Benj. F. Moore, of Victor, Iowa.

The wire now has a cross section of 0.11 inches by 0.19 inches, having suffered little metal loss, as evidenced by the fact that the barbs are still tightly wound.

Chemical analysis revealed this to be a copper bearing steel, probably made by the basic open hearth process, judging from its relatively low phosphorous content. Complete chemical analysis was as follows:

	C*	Mn	P	S	Si	Cu	Ni
%	.10/.15	.28	.026	.067	.01	.35	.02

*(Estimated from metallographic examination)

It is doubtful that the copper was added intentionally, for little was known 75 years ago about its beneficial effect on atmospheric corrosion resistance. Not until 1919 did D. M. Buck[1] report that copper additions improved atmospheric corrosion resistance of steels. One can only assume that the copper was an accidental impurity occurring in the iron ore from which the steel was made.

With present day knowledge of the effects of alloying additions to steel and the differences in corrosivity of various atmospheres, it is not particularly surprising to find installations such as this, which are continuing to serve mankind. The dense, protective, rust coating which has developed on this wire has greatly decreased to corrosion rate of the wire and it could be anticipated safely that many more years of useful service will be obtained from the fence on this Iowa farm.

It is gratifying to the corrosion researcher to encounter service installations such as this, for they serve to substantiate the quantitative data collected from systematic test programs, which of necessity, must be of only a few years' duration.

*Corrosion Engineering Section, The International Nickel Co., Inc., New York.

1. D. M. Buck "The Influence of Very Low Percentages of Copper in Retarding the Corrosion of Steel." Proc. *Amer. Soc. Testing Mat.*, Vol. 19, Part 2, 224-237. (1919).

Ohio Valley Sanitation Commission Reports Gains

Sewage-disposal facilities to purify wastes from more than four million people are in operation in the Ohio Valley and more are approved or under construction to treat sewage from an additional estimated 3,260,000 according to the Sixth Annual Report of the Ohio River Valley Water Sanitation Commission.

The report shows that 45 percent of the 155,000 square mile area of Indiana, Illinois, Kentucky, New York, Pennsylvania, Virginia and West Virginia that constitutes the interstate drainage district are served by sewage treatment plants; nine percent has plants under construction and 26 percent has plans approved for construction. Of 1190 industries discharging directly into streams of the district the industrial waste control of 361 is rated as adequate, 429 provide some form of control but more will be required, 32 new installations are under construction and 129 new facilities are in the planning stage.

The report points out that a major accomplishment of the commission during the past year was the completion of engineering studies, public hearings and the promulgation of requirements for sewage discharges in the entire 981 miles of the Ohio River.

According to the report quantity of flow and the quality variations of water in the river receive special study by the commission. The river is monitored twice weekly at ten sampling stations and data furnished by managers of municipal and industrial water supply systems provides constant check on pollution conditions and is aiding the commission in determining remedial measures. The report also includes information on compliance status of cities in the area, financial statement, commissioners and committees and treatment standards No. 5, 6 and 7.

BOOK REVIEWS

Tentative Specifications for Nickel and Nickel Base Alloy Covered Welding Electrodes. 6 x 9 inches, 12 pages, paper cover. 1954. The American Welding Society, 33 West 39th St., New York 18, N. Y. and American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy, 25c.

Standard requirements for nickel and nickel-base alloy covered welding electrodes for welding nickel and nickel-base alloys individually to themselves and for welding them to steel are listed. Filler metals for welding the clad side of nickel-base alloy clad steels are given.

Twelve classifications of filler metal include nickel, Monel, K Monel, Inconel, Inconel X and various Hastelloy alloys.

Metallkunde. (In German.) 6 x 9 inches, 204 pages plus viii. Cloth. 1954. By William M. Guertler. Gebruder Borntraeger. An Der Rehwiese 4, Berlin-Nikolasee, Germany. Price not indicated.

Essentially a text on the characteristics of metals, this well-illustrated book describes metals, differences among metals, how metals are used, selection of best metals for specific uses, characteristics of crystal structure, atomic structure, melting characteristics, microscopy, strength characteristics and numerous other data.

It is fully illustrated with diagrams showing theoretical arrangements of internal structure, crystal size and shape, with graphs of data on mechanical characteristics.

There is an alphabetical subject index.

The Corrosion Resistance of Tin and Tin Alloys. 9¾ x 6 inches, 77 pages, paper. April 1952. Tin Research Institute, Fraser Rd., Greenford, Middlesex. Per copy three shillings and sixpence.

An excellent book by S. C. Britton, head of Corrosion Department, Tin Research Institute. It is in three parts. The first, Corrosion of Tin, provides information on corrosive aspects of atmosphere, acids, alkalis, near-neutral aqueous media, milk products, sulfur compounds in aqueous solutions, non-aqueous solutions and impurities. Part II, Alloys of Tin deals with corrosion characteristics of pewter and Britannia metal, solders and fusible alloys, bearing metals and coppertin alloys. Part III, Coatings of Tin and Tin Alloys provides material on coatings of alloys which have their main use as coatings and those of other alloys and of tin whose performance cannot be divorced from effects of the basis metal exposed at their discontinuities.

Payment of 1954 Membership Dues

In order to avoid interrupted mail and missed copies of CORROSION all NACE members who have not done so already are urged to remit their 1954 MEMBERSHIP DUES before March 31. Association by-laws require that the names of those whose dues are not received by March 31 be dropped from the membership mailing list.

NEW PRODUCTS —Materials—Service—Literature

Pipeline Coating and Engineering Co., has appointed Frost Engineering Service Co., Los Angeles as distributor for Plico products in Southern California, Arizona, New Mexico and southern Nevada.

•

Atlastic 60, a hot-poured cement produced by Atlas Mineral Products Co., Mertztown, Pa., is said to have excellent adhesion to ceramic surfaces and can be used successfully to join vitrified clay pipe to provide chemical resistant joint. The company also produces Urefoam and Cyofoam which it says have been used for foamed-in-place thermal and sound insulation as well as for reinforcing and filling of voids to produce strong, lightweight structures.

•

Anti-Corrosive Metal Products Co., Inc., 1214 River Rd., Castleton-on-Hudson, N. Y., produces Nylo-Fast, an all-nylon fastener which it says is only 1/6 the weight of stainless steel and 1/2 the weight of aluminum with characteristics including give and take against other surfaces and locking in place to eliminate loosening under vibration. Manufacturer claims fastener will resist high voltages at commercial frequencies, withstand heat up to 450° F and is unaffected by commercial solvents, alcohols, gasoline, oils and boiling 40 percent caustic soda. A folder describing properties of fastener is available from the company.

•

A Two-Wire Thermocouple encased in stainless steel tubing is produced by Industrial Division of Minneapolis-Honeywell Regulator Co. Manfacturer claims tube is expected to double life of thermocouples and accuracy of device is rated at plus or minus 5 degrees F over a range from 0 to 1000 degrees F. Fiberglass insulation in thermocouples permits greater application flexibility than is possible with ceramic-insulated pencil-type models, the company says.

•

General Electric Co., Nela Park, Cleveland 12, Ohio, announces plans to make pure tungsten and molybdenum products generally available to open market. Tungsten currently is used for such items as electric lamp filaments, carbide cutting tools, grids in electronic tubes, electric contacts, welding electrodes and metallizing filaments. Pure molybdenum is used in various forms as parts of electric lamps and electronic tubes and equipment. Company is building $1,700,000 laboratory-pilot plant to further efforts to develop tungsten and molybdenum products and to improve existing ones. Structure is expected to be completed late next summer, the company reports.

•

Mang-Trode, a covered manganese bronze electrode for high speed metal-arc welding of manganese bronze and yellow brass castings and sheet and plate is produced by Weldrod Department of Ampco Metal, Inc., Milwaukee, Wisconsin. Electrodes operate at relatively high current densities on reverse (positive) polarity, direct current for fast deposition. Arc action is smooth, spatter losses are low and electrode can be applied at room temperatures without excessive preheat and interpass temperatures required by other methods the company says.

(Continued on Page 105)

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NEW PRODUCTS

(Continued From Page 104)

Self-Molding packing and sealing compounds are described in an eight-page folder entitled "Did You Ever Meet Your Silent Partner?" available from Surveys, Inc., 219 Euclid Ave., Trenton, N. J.

•

Tabulation of military and government specifications for Nema grades of thermosetting laminated plastics has been compiled in chart form by Synthane Corp., Oaks, Pa. The one-page, 8½ x 11 inch chart describing composition of 24 grades of tubing, rods and sheet stock is available from Herbert Widdop, Synthane Corp., Oaks, Pa.

•

Walk-in Test Chamber that artificially reproduces temperature, humidity and altitude and a pulp bleach plant operated by one man from "brain center" are two technological developments reported in Fourth Quarter, 1954 issue of Instrumentation, the technical publication of Industrial Division, Minneapolis-Honeywell Regulator Co. Other articles describe a "super-computer" used in development of new aircraft, use of microwave recording-telemetering system to centralize control of power generation, control of production of quality glassware and use of electronic instruments to regulate heat-treating operations.

•

Nialite, an alloy of copper, nickel, aluminum and other elements is produced by Baldwin-Lima-Hamilton Corp., Philadelphia, Pa. It is zinc-free, eliminating problem of dezincification frequently occurring with manganese bronze propellers. Cavitation and impingement tests indicate resistance to cavitation in ratio of 4 to 1 and 6 to 1 over manganese bronze, the company reports. Comparative tests made by the Naval Research Laboratory indicate a corrosion fatigue limit in salt water of 12,000 psi for manganese bronze and 20,000 for Nialite.

•

Atlas Mineral Products Co., Mertztown, Pa., produces Neobon, an on-the-job mixed heavy rubber coating; Neelium, a high solids high built liquid Neoprene coating, and Elprene, a liquid Neoprene maintenance coating. Products are available in gray and black and can be applied to metal or concrete surfaces over Neobon priming system.

•

Conversion by bombardment in a nuclear reactor of polyethylene into a new type of polymer substance that is flexible, non-crystallized, largely transparent and virtually without a melting point is described in a publication of Isotope Products Limited, Oakville, Ont. In another case, use of radio-active bromine to locate buried pipe leaks is also related. The bromine solution was pumped into the pipe. Then the pipe was flushed with water. Radioactive counters then located those spots where the radioactive solution had leaked into the ground.

•

Type 2 Bi-Seal, a black polyethylene base tape with low vapor transmission rate is available from Bishop Manufacturing Corp., Canfield Rd., Ceder Grove, N. J.

•

Boltaron polyvinyl chloride blowers made by Industrial Plastic Fabricators, Inc., Endicott St., Norwood, Mass. are recommended for use in exhausting corrosive gases and fumes.

•

Allyl-Phenolic heat cured linings for storage and processing equipment are installed by Stalpic Division, A. Gusmer, Inc., Woodbridge, N. J. The linings are odorless and tasteless after curing at steel temperatures from 340 to 370 F. Sterilizing with steam at pressures up to 10 psi has no effect on the linings. A bulletin is available on request.

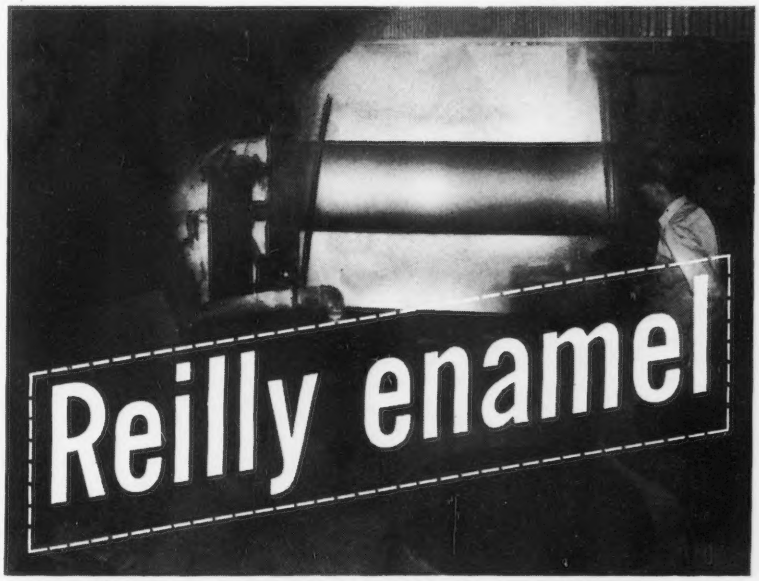
•

Neovane rubber impeller pumps have marine bronze bodies and stainless steel shafts. They can be used for liquids and small solids at temperatures between 0 and 175 F. Manufacturer is Lee Healey Co., 554 West Garfield Ave., Glendale 4, Cal.

Alcoplate, a variant of the Kanigen process developed by the General American Transportation Corp., permits chemical deposition of nickel on inexpensive basis metals without regard to the complexity of their surfaces. The resulting coating is said by the company to have zero porosity, excellent adhesion and corrosion resistance better than pure or wrought nickel. Production facilities for Alcoplate were developed by the American Locomotive company at its Dunkirk, N. Y. plant where extensive plating is underway on components for use on atomic energy installations.

Two continuous-flow methods are in use at the Dunkirk plant, one for internally coating by a closed-cycle method and the other for internal and external coating by an immersion process.

(Continued on Page 106)



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*Photograph courtesy of Crutcher-Rolf-Cummings, Inc., Houston, Texas

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NEW PRODUCTS

(Continued From Page 105)

Agilene-HT, a material developed by the American Agile Corp., Maple Heights, Ohio consists of ordinary polyethylene subjected to high energy atomic bombardment. The resulting changes in the molecular cross-linkages make a stronger structure, an effect similar to vulcanization in rubber. Increase in heat resistance permits form stability under no load at temperatures up to 350 F; tensile strength and elongation are improved and solvent resistance at high temperatures is improved. The irradiated material shows no sign of stress cracking even when exposed to acetic acid, acetone and detergent solutions. The material presently is being fabricated into standard laboratory items and custom-fabricated items of limited size.

•

BJ Chemical Pumps, with corrosion-resistant catch basins, snap-on synthetic rubber glands to guard against acid spray, synthetic rubber deflector and stainless steel labyrinths to guard against liquid entrance to bearings are made by Byron Jackson Co., Pump Division, P. O. Box 2017, Terminal Annex, Los Angeles 54, Cal.

•

Rigimesh, made by welding together the warp and woof strands of one or more layers of woven wire cloth and mechanically treating them to produce a homogeneous plate having much finer openings but with uniformity of the starting material is produced by Aircraft Porous Media, Inc., Glen Cove, N. Y.

•

Standard Steel Works Division of Baldwin-Lima-Hamilton Corp., produces forged ring flanges for manholes and larger openings with diameters from 24 to 84 inches in glass-lined tanks which it says increase normal pressure capacities 50 percent above limits reached with integral flanges formed in tank wall or flanges formed from steel plate and welded to tank shell. Company claims use of forged ring flanges by The Pfaudler Co., manufacturers of glass-lined tanks results in elimination of serious warping problem during heat treatment; increased production, because user requirements are more nearly satisfied and lead into development of glass-lined tank design capable of withstanding pressures of 100 to 300 pounds per square inch.

•

Copperweld products are described with illustrations and charts in a seven-page pamphlet published by Wire and Cable Division of Copperweld Steel Co., Glassport, Pa.

•

Camac Cast Steel centrifugal pumps for handling alkaline solutions such as cyanide and caustic and acids such as chromic are produced by Carl Buck & Associates, Essex Fells, N. J. Seal of unit is Camac Special Acid or Teflon and can be water-cooled or not. Design is heavy for rough chemical service and heads of 10 to 150 feet can be provided with flows from 10 to 200 gpm.

•

Permatex Co., Inc., Brooklyn 35, N. Y., produces Permatex aviation and industrial chemical sealant No. 1372 which it says maintained unbroken seal in strenuous laboratory test conducted by engineers of Titeflex, Inc., producers of flexible metal hose and ignition harnesses used in reciprocal and jet aircraft engines. In tests, tube hose assembly was mounted to unground bolted flange face at one end and pressure was applied by use of Marman clamp on opposite end. Extreme temperatures and vibration were applied to test assembly for period of 250 hours and no leaks developed. Tests proved sealant formed leakproof assembly even after connections had been disassembled and re-assembled without requiring new gasket, the company says. Objective of test was to demonstrate effectiveness of sealant in forming pressure tight seal that would be leakproof at temperatures as high as 650 degrees F, withstand internal pressure of 165 psi and hold seal under vibration of 142 cps with a double amplitude at .012.

•

V. W. Eckel, Northridge, Cal., and Aero Supply Manufacturing Co., Inc., Corry, Pa., have entered an agreement under which Aero Supply will produce and sell a solenoid-operated shut-off valve about one-half size and weight of most conventional type units according to joint announcement by the companies. Valve is coaxial, the flow passage, valve poppet and valve seat located within core of coil. Manufacturer recommends use in virtually any operating medium since inert materials are employed in construction of unit. Smallest unit weighs 1¾ ounces, has equivalent flow orifice of 1/32-inch in diameter, will open against 200 psi at 17 volts dc with an effluent temperature of 500 F and is furnished either normally open or normally closed.

•

Bakelite C-8 epoxy resins are described in Technical Bulletins Nos. 1, 2 and 3 available from Bakelite Company, a Division of Union Carbide and Carbon Corp., 300 Madison Ave., New York 17, N. Y. The six-page folders contain specific data on physical properties of individual resins and hardeners together with physical, chemical and electrical properties of recommended resin-hardener combinations. Included in each bulletin is list of experienced compounders equipped to render technical assistance and supply specially formulated compounds for particular end uses.

•

Hi-eF, an internal type purifier (scrubber) for delivering clean vapor and gases from such items as steam drums, evaporators, bubble-cap towers and stills is described in the four-page Condensed Bulletin 103 available from The V. D. Anderson Co., 1935 W. 96th St., Cleveland 2, Ohio.

•

Stevens Technical Bulletin P-131 published by Frederic B. Stevens, Inc., Detroit 16, Mich., provides information on Stevco Bright Cadmium Process which is said to be designed to supply demands of industry for bright cadmium deposits to meet definite thickness of deposit and corrosion protection specifications for iron and steel plating.

•

Practical Grounding is title of 35-page booklet reviewing principles and practices of grounding. Booklet tells where and how to use deep grounding and aids in planning of reliable low-resistance ground connections. It is published by Wire and Cable Division of Copperweld Steel Co., Glassport, Pa.

(Continued on Page 108)

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NEW PRODUCTS

(Continued From Page 106)

Tuff-Tite, a multi-purpose fastener with one-piece metal washer-head and assembled neoprene washer is produced by Townsend Company for use in preventing leaks, protecting surfaces, absorbing shock and stopping squeaks. When fastener is seated undercut in washer-head traps and controls flow of neoprene at outside edge forming water-tight and air-tight seal, the company says. Manufacturer claims neoprene washers retard electrolysis between dissimilar metals by insulating against direct contact and that flat, convex or concave surfaces are no problem because washers flow in any direction to conform with contours of surface. Conical design of washer helps lock neoprene to threads of fastener and force neoprene into hole and around threads. Neoprene is synthetic rubber and resists abrasion, sunlight, aging, ozone and heat and performs effectively in temperatures ranging from minus 65 to plus 250 degrees F, the company reports.

•

Expansolin, a ceramic material produced by Enjay Maintenance Engineers, 327 Union Ave., Rutherford, N. J., is said to have ability to expand and contract with iron or steel to which it is bonded. Manufacturer reports lining system called Enjay system using the material results in lining with excellent adhesion, complete inertness to hot or cold water, no chance of contaminating contents, resistance to sludge and lime build-up, increased heat exchange rates and good insulating value.

•

Various Uses of Al-Fin, a casting process for molecular bonding of aluminum and magnesium and their alloys to steel and cast iron or nickel and titanium are described in the September issue of Bonded Bi-Metallics News published by Al-Fin, a Division of Fairchild Engine and Airplane Corp., Farmingdale, L. I., N. Y.

•

Chempro Aluminum Can is described in a one-page Technical Data Sheet No. CP-5 published by Chemical & Power Products, Inc., 11 Broadway, New York 4, N. Y.

•

Amourvin, an industrial tubing is described in a four-page folder published by Newage International, Inc., 235 E. 42nd St., New York 17, N. Y.

•

Marvibond, a vinyl-on-metal laminated material said to combine corrosion resistance of vinyl plastic with formability of metal is produced in coil form by Enamelstrip Corp., Allentown, Pa., under license by United States Rubber Company. Manufacturer claims laminate can be deep drawn, sheared, crimped, bent, embossed, drilled, roll formed and punched with standard tools without damage to coating or bond and that vinyl will not chip, crack, craze or flake off. Material resists acids, alkalies, salt water, alcohol, household chemicals and corrosive industrial liquids and atmospheres and withstands weather and humidity indefinitely, the company reports.

•

Corrosion and Corrosion Prevention are included as subjects for students taking graduate courses in chemistry and chemical engineering at Stevens Institute of Technology, Fifth and Hudson Sts., Hoboken, N. J.

•

Teflon flexible sealing members plus springs and metal parts in materials suitable for liquids pumped make mechanical shaft seals developed by Crane Packing Company, Chicago, resistant to corrosion. The seals are applicable to all modern slit-case pumps.

•

Transparent plastic mass-produced isolation and atmosphere control hoods for use under closely controlled conditions are available from P. M. Lennard Co., Inc., 671 Bergen St., Brooklyn 38, N. Y. Complete control of relative humidity, temperature, internal atmosphere, bacterial or fungi contamination or isotope or dust exposure is provided.

•

Logan Clay Products Co., Logan, Ohio is producing a vitrified clay gutter and curbing product designed to handle corrosive industrial wastes. Detailed information is available.

•

Tinker & Rasor, P. O. Box 281, San Gabriel, Cal. is now making its Model M-1 holiday detector designed for use with films of relatively high electrical resistance on materials of low resistance. A dampened sponge is used as an exploring electrode and a bell signals a void. The unit is carried in a leather case, weighs less than 3 pounds and uses only 67.5 volts potential.

•

Methods for checking ferrous metal objects for surface discontinuities are described in an 8-page booklet entitled Norelco Portaflux—New Portable Magnetic Particle Test Unit, which is available at no cost from the Mount Vernon Division, North American Philips Co., Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

•

International Nickel Co., Inc., 67 Wall St., New York 5, has published Bulletin A-69, a 28-page basic reference bulletin compiled primarily for design engineers. Booklet presents many characteristics of modern nickel cast irons and illustrates their acceptance throughout industry. Fifty illustrations indicate wide industrial use of nickel and 27 tables, charts and photomicrographs show how by use of nickel alone, or in combination with other alloying elements, engineering properties of cast iron can be controlled to meet service requirements.

•

Spencer Rubber Products Co., Manchester, Conn., produces the Moorhead Roll-Lock Grommet which it says has primary purposes of parts positioning, vibration dampening and electrical insulating and can serve as a seal against water, dust, air, moisture, chemicals and solvents. Manufacturer recommends product for outboard or overhung loads such as lamps or switches or small assemblies of any kind and as shock mounts or "feet" for instruments, electric motors, portable machines and motion picture projectors.

•

Alodine No. 1000, a method for providing invisible protection for aluminum and its alloys is described in a three-page pamphlet published by the American Chemical Paint Co., Ambler, Pa.

Lamicor, a glass-fiber reinforced polyester resin laminate is said to be stronger than steel and lighter than aluminum. Strick Plastics Co., 31-06 38th Ave., Long Island City 1, N. Y., manufacturers of the product report it shows no bad affects when used over long periods of time with acids, gasoline and petroleum products at temperatures of more than 200 F. Product will not corrode, mildew and is not affected by fungi, vermin or termites, according to the company.

•

A 12-page brochure treating with the process of design, manufacture and final application of Lebanon centrifugal castings is available by writing on company letterhead to William H. Worrilow, Jr., General sales manager, Lebanon Steel Foundry, Lebanon, Pa.

PERSONALS

C. E. Thorney, Jr., has joined the Houston sales force of Revere Copper And Brass Inc.

•

Cordell Garner has been named sales manager of Tubular Division of Plastic Applicators, Inc., Houston.

•

Fred W. Arndt has been named chief engineer of Heil Process Equipment Corp., Cleveland. **Peter L. Veit** has been appointed sales engineer for the company.

•

Robertshaw-Fulton Controls Co., has named four new members of its Aeronautical Division research and development laboratory. They are: **Leland G. Cole,** director of the dynamics laboratory; **W. M. Roberds** and **Maynard D. McFarlane,** research scientists and **C. J. Thompson,** chief design engineer.

•

George W. Kessler has been appointed chief engineer of the Boiler Division, The Babcock & Wilcox Co., 161 E. 42nd St., New York City.

•

The Metropolitan Refining Co., Inc., Long Island City, N. Y., has named **Frederick S. Hodgdon** associate chief engineer for problems pertaining to water treatment in air conditioning and allied equipment.

•

Daniel H. Dykins has been appointed manager of Utilities of The Kuljian Corp., engineers and constructors, 1200 N. Broad St., Philadelphia 21.

•

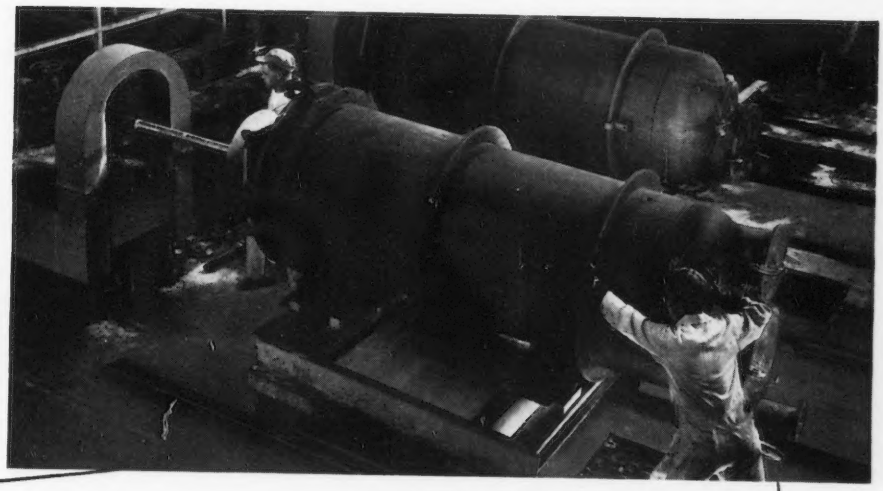
Joseph G. Surchek has been appointed senior research leader, Rust Preventives of Dearborn Chemical Co., Merchandise Mart Plaza, Chicago 54. This post will be in addition to Mr. Surchek's duties in field technical service division and assisting in maintenance of field contact with suppliers and governmental agencies.

•

James B. Morey has been named in charge of the Cincinnati Technical Field Section, Development and Research Division of International Nickel Co., Inc., 67 Wall St., New York 5. **William S. Mounce** has joined the division's staff in New York as member of the Constructional Alloy Steel Section.

ALCOPLATE*

Chemically Coats any Metal Surface with Protective Nickel



A pressure vessel is positioned for internal coat of ALCOPLATE. In addition to operating one of the largest plants for chemical nickel-plating, ALCO has complete facilities and extensive experience in the design and fabrication of heat exchangers, pressure vessels, etc.

Solves Corrosion Problems in the Chemical, Petrochemical and Related Industries At Low Cost

No matter how intricate the geometries involved—on surfaces impossible to plate electrolytically or to clad—ALCOPLATE provides a uniform coating of protective nickel. Applied to inexpensive base metals, its corrosion resistance *is as good as or better than* pure or wrought nickel or other costly alloys. It will pay for itself many times over through prolonged life of process equipment.

Other important advantages of ALCOPLATE are:

1. Maximum protection at minimum plating coat—Zero porosity is obtained in plating coats of less than a half mil (.0005).

2. Plate adhesion is excellent—Steel specimens pulled to the yield point show no flaking or spalling.

3. Plate thickness is uniform—Costly overplating is eliminated because ALCOPLATE deposits vary less than 10 per cent from specifications on any surface.

4. Resistance to abrasion—Hardness averages 48 Rockwell C and can be increased to 66 Rockwell C through post-plate heat treating.

5. Appearance of plate—A polished appearance can be obtained by polishing the base metal prior to plating. ALCOPLATE can be buffed to a high luster.

Learn how ALCOPLATE can solve your corrosion or product contamination problems. Details on the application of ALCOPLATE to your needs can be obtained from any of the ALCO sales offices listed below.

ALCO

AMERICAN LOCOMOTIVE COMPANY

BEAUMONT, TEXAS	1400 Crockett St.
CHICAGO, ILL.	909 McCormick Bldg.
CLEVELAND, OHIO	Terminal Tower Bldg.
HOUSTON, TEX.	1404 Dunlavy St.
KANSAS CITY, MO.	606 Commerce Trust Bldg.
LOS ANGELES, CALIF.	3035 East 46th St.
NEW YORK, N. Y.	30 Church St.
PITTSBURGH, PA.	527 Frick Bldg.
ST. LOUIS, MO.	4050 Bingham Ave.
ST. PAUL, MINN.	635 Prior Ave. N.
SAN FRANCISCO, CALIF.	235 Montgomery St
TULSA, OKLA.	200-206 North Denver St.
WASHINGTON, D. C.	910 17th St., N.W.

*ALCOPLATE—Trade-mark registration applied for. Application of the Kanigen® process. "Kanigen" is a mark identifying chemical deposition of high nickel, low phosphorus alloy by General American Transportation Corporation and its licensees, and the coating resulting therefrom.

LETTERS to the EDITOR

Corporate Membership, Its Advantages, Importance and Potential.

By Alvan E. Richey

Your National Association of Corrosion Engineers has three types of membership: Corporate, Active and Junior. Because the rapid growth of the association and its many activities requires income far beyond the amount realized from dues alone, Corporate membership group was established, a special preferred membership contributing to the financial well being of the association.

For these extra contributions Corporate members are accorded full recognition and honor. A separate section of the annual roster lists this group. Most local sections hold annually a Corporate membership meeting with this group as honorees. Plans are now afoot to so honor the Corporate membership at national conferences. Copies of all Technical Committee reports are mailed them for dissemination within their companies. Five NACE directors are elected from this Corporate membership group. Their guiding influence is thus felt in all work of the association.

How important the Corporate membership is may best be shown by a review of NACE income and expense for the past two years:

Dues Are Increased

This year Active membership dues were increased from $7.50 to $10 yearly to narrow the gap between regular business income and expense. This will bring approximately $6000 more annually. The real solution, however, lies in a healthy increase in Corporate members. Corporate membership income was more than 64% of the total of regular business income for both years shown. CORPORATE MEMBERS are the sustaining group. Need a more graphic illustration of its importance be given?

Let us take the time to properly recognize and fully develop this type of membership. A rule-of-thumb ratio of one Corporate member to ten Active members is realistic. It can and should be obtained. How? Why by the elemental process of bringing the advantages of Corporate membership to the attention of suitable prospects. Those who are interested in NACE and are shown the importance of Corporate membership and its advantages, will join. Is your own company a Corporate member? Does it benefit to the amount of $100 annually through NACE's correlation of study and research on corrosion problems, equipment and design in corrosion control; its fostering of cooperation among individual companies in the joint solution of common corrosion problems?

Obtain a new Corporate member for the NACE. You will profit in developing the contact and your local section will receive direct, tangible benefit. The NACE and the new Corporate member you've obtained will both thank you. Your section secretary will gladly supply Corporate Membership Application Forms.

Tennessee University Short Course Program Includes Speakers, Films and Discussions

Fundamentals of corrosion will be stressed by instructors with years of experience in corrosion mitigation during the three-day University of Tennessee Corrosion Conference scheduled to be held March 1-3, 1955.

Following is the tentative program:

Tuesday, March 1

8:30-9:30 a.m.—Registration and films on Corrosion Costs and Heat Treating Fundamentals.
Morning Session Chairman, E. P. Tait, Alloy Steel Products Co.
9:30-10—Welcome address.
10-10:55—Introduction to Corrosion by Anton deS. Brasunas, University of Tennessee.
11:05-12—Atmospheric Corrosion by H. R. Copson, International Nickel Co., Inc.
Afternoon Session: Chairman, Ivy M. Parker, Plantation Pipe Line Co.
2-2:55—Coatings for Atmospheric Corrosion Protection by J. I. Richardson, Amercoat Corp.
2:55-3:50—Corrosion at High Temperatures by M. A. Hunter, Rensselaer Polytechnic Institute.
4-5—Catastrophic Corrosion by H. H. Marvin, General Electric Research Laboratory.
Evening—Corrosion In Action (film).

Wednesday, March 2

Morning Session: Chairman, Francois Kertesz, Oak Ridge National Laboratory.
8:30-9—Liquid Metal Corrosion by E. E. Hoffman, Oak Ridge National Laboratory.
9-9:30—Molten Salt Corrosion.
9:30-10:25—Corrosion Problems in Power Plants by R. M. Lemen, The Permutit Co.
10:35-11:30—Principles of Underground Corrosion by I. A. Logan, National Bureau of Standards.
11:30-12:25—Unusual Practical Problems In Pipeline Corrosion by H. C. Van Nouhuys, Southeastern Pipe Line Co.
Afternoon Session: Chairman, E. E. Stansbury, University of Tennessee.
2-2:55—Use of Plastics and Plastic Liners for Corrosion Protection by R. B. Seymour, Atlas Mineral Products Co.
2:55-3:50—Influence of Mechanical Factors On Corrosion by J. J. Harwood, Office of Naval Research.
4-4:55—Principles of Cathodic Protection by Milton Stern, Union Carbide and Carbon Research Laboratory.
Evening Session: Banquet. Principal speaker, A. B. Campbell, Executive Secretary, National Association of Corrosion Engineers.

Thursday, March 3

Morning Session: Chairman, J. L. English, Oak Ridge National Laboratory.
8:30-9:25—Corrosion By Sea Water by T. P. May, International Nickel Co., Inc.
9:25-10:20—Corrosion By Chemical Solutions by Frederick Fink, Battelle Memorial Institute.
10:30-11:25—Corrosion Failures In Chemical Industries by Mars. G. Fontana, Ohio State University.
11:25-12:20—Corrosion Inhibitors by Harry C. Gatos, E. I. du Pont Engineering Research Laboratories.
Afternoon Session: Chairman, Anton deS. Brasunas, University of Tennessee.
2-2:55—Passivation Of Stainless Steels by N. A. Nielson, E. I. du Pont Engineering Research Laboratories.
2:55-3:50—Nature Of Metals and Alloys by E. E. Stansbury, University of Tennessee.
4-4:15—General questions on corrosion fundamentals.
4:15-5—Four simultaneous round table discussions on corrosion control practice.

Short Course Held by Canadian Region Feb. 2-4

A short course in corrosion jointly sponsored by the Canadian Region NACE and Southern Ontario Committee on Electrolysis was held on the University of Toronto campus, February 2-4. Lecturers were: G. R. Connor, Alchem, Ltd., Burlington, Ont.; W. F. Fair, Koppers Co., Ltd., Verona, Pa.; W. Z. Friend, International Nickel Co., Inc.; R. B. Hoxeng and V. V. Kendall, U. S. Steel Corp., Pittsburgh; A. R. Murdison, Imperial Oil Ltd., Toronto and W. F. Graydon, F. E. W. Wetmore and W. C. Winegard, University of Toronto.

1953

	Income	Expense	Balance
Regular Business:			
Dues:			
Corporate	$ 33,775.90		
Active	15,067.80		
Junior	127.50		
Total	48,971.20		
Miscellaneous	2,730.25		
Total	51,701.45	$ 72,271.67	$—20,570.22
Publications	136,188.04	117,995.57	+18,192.47
Conference	43,538.50	19,530.08	+24,008.42
	$231,427.99	$209,797.32	$+21,630.67

1954 (Estimated)

	Income	Expense	Balance
Regular Business:			
Dues:			
Corporate	$37,400.		
Active	17,775.		
Junior	125.		
Total	55,300.		
Miscellaneous	2,900.		
Total	58,200.	$80,000.	$ —21,800.
Publications	151,000.	149,300.	+ 1,800.
Conference	49,039.	25,281.	+23,758.
	$258,339.	$254,581.	$ +3,758.

Corrosion Abstracts

CORROSION CONTROL — PROTECT INDUSTRY — NATIONAL ASSOCIATION OF CORROSION ENGINEERS

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1. GENERAL

1.2 Importance

1.2.2, 8.4.3

What Does Corrosion Cost You? *Petroleum Processing*, **8**, 1685-1688 (1953) Nov.

Estimates made following a countrywide refinery survey indicate corrosion cost of nine cents per bbl. of crude processed. This figure includes cost of material and labor for repairs on a corroded unit or equipment, 70% of the running maintenance cost of the item assigned to the corrosion factor, and an accelerated depreciation allowance, but not the cost of protective chemicals, coatings, cathodic protection or other measures of a permanent kind. A table shows the possible overall cost of corrosion to 35 companies, based on the average cost of nine cents/bbl. of crudes processed in 1952. The nine-cent estimate is believed to be conservative as compared with unpublished findings of the API Refinery Division Sub-committee on Corrosion. An analysis of the company statements indicates that technologists differ as to whether or not unit corrosion cost has been lowered in recent years. 7823

1.5 Directories of Material

1.5, 6.1

Materials of Construction for Chemical Engineering. *Ind. and Eng. Chem.*, **45**, 2171-2282 (1953) October.

This 7th edition of the annual review contains the papers "Aluminum Alloys", Harry W. Fritts; "Carbon and Graphite", W. M. Gaylord; "Cements", C. R. Payne; "Elastomers", Harry L. Fisher; "Fibers", C. S. Grove, Jr., Joseph L. Vodonik, and Robert S. Casey; "Iron, Mild Steels, and Low-Alloy Steels", Homer L. Shaw; "Lead and Lead Alloys", Kempton H. Roll; "Nickel and High-Nickel Alloys", H. O. Teeple; "Paints", Francis Scofield; "Plastics", Raymond B. Seymour; "Stainless Steels and Other Ferrous Alloys", W. A. Luce; "Tin and Its Alloys", Robert J. Nekervis; and "Less Common Metals", Wilfred R. Bekebrede and L. F. Yntema. 1969 references.--BTR. 7779

1.5, 6.5

Non-Ferrous Metals in Chemical Engineering. *Met. Ind.*, **83**, No. 10, 182-194 (1953) September 4.

A series of short articles. S. Baker,

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CODE OF AGENCIES SUPPLYING CORROSION ABSTRACTS

Neither NACE nor the sources listed below furnish reprint copies.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Ontario.

AWWA—Journal, American Water Works Association, Amer. Water Works Asoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CBEC—Centre Belge d'Etude de la Corrosion (CEBELCOR), 17 re des Drapiers, Brussels, Belgium.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

IIM—Transactions, The Indian Institute of Metals, 23-B, Notaji Subhas Road, P. O. Box 737, Calcutta, India.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W.1, England.

JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguro-ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana, Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

SE—Stahl Und Eisen, Verlag Stahleisen, M. B. H., Dusseldorf, August-Thysen Str. 1. Postscheck Koln 4110, (22a) Dusseldorf, Germany.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

"Copper and Copper Alloys"; D. S. Laidler, "Lead and Lead Alloys"; "Wrought Nickel-Molybdenum-Iron" (Corronel B; a corrosion resistant material); J. M. Pirie, "Silver and Platinum Metals"; D. C. G. Lees, "Aluminum and Its Alloys"; J. F. Lancaster, "Fabricating Chemical Plant". —BNF. 7818

1.6 Books

1.6, 5.1

Corrosion. *Butterworth's Scientific Publications,* London. Book, 1953, 60 pp.

This book consists of the series of papers on corrosion which were published in: *Research,* **5** (1952). Contents: W.H.J. Vernon, "Metallic Corrosion"; K. N. Barnard, "Prevention of Corrosion of Ships in Sea-Water by Means of Cathodic Protection"; K. N. Barnard, "Prevention of Corrosion of Ships in Sea-Water. II.—Cathodic Protection by Impressed Currents"; U. R. Evans, "Prevention of Corrosion by Metallic Coatings"; J. E. O. Mayne, "The Protective Action of Paints"; R. S. Thornhill, "Prevention of Corrosion by Means of Inhibitors"; S. C. Britton, "Corrosion Testing"; H. L. Bennister, "Vapour-Phase Inhibitors".

While a short series written by people all of whom are authorities on corrosion subjects is bound to be interesting, it is unfortunately almost equally bound to appear lopsided and incomplete when presented in book form. To give only one example, Dr. Evans' paper, while in itself a useful 5-page summary of the theory of corrosion protection by metallic coatings, contrasts with 9 pages written on the very specialized subject of vapor phase inhibitors. On the whole, too, the subjects not dealt with are rather more numerous than the ones that are. Within these limitations, however, the volume is a useful and, incidentally, inexpensive theoretical introduction to several aspects of corrosion. 7869

2. TESTING

2.1 General

2.1.1

Analysis and Correlation of Test Data. I. W. Burr. *Metal Progress,* **64,** No. 4, 112-118, 282, 284 (1953) October.

A discussion of statistical methods.—BNF. 7670

2.1.1, 2.2.1, 2.3.1

Corrosion. How Best to Study It. *Metal Progress,* **64,** 100, 170, 172-174 (1953) December.

Includes "For More Fundamental Research", John Chipman and "A Defense of Ad Hoc Studies", Frank L. Laque. Discusses relative merits of fundamental and empirical studies.—BTR. 7874

2.3 Laboratory Methods and Tests

2.3.4, 1.6

Select Methods of Metallurgical Anaylsis. W. A. Naish, J. E. Clennell and V. S. Kingswood. Book, 1953, 660 pp. Chapman & Hall Ltd., London.

A completely revised edition of the book first published in 1929, retaining the original format, and written by an editorial panel of specialists. There are six sections, the last containing a chapter on modern physico-chemical methods of analysis. Here electrometric titrations, absorptiometry and colorimetry, polarography, spectroscopic analysis, and quantitative analysis by means of the spark discharge are all dealt with briefly. An appendix covers standard solutions, atomic weights, gravimetric factors and the use and care of platinum apparatus. Methods are given for the determination of a large number of elements in commercial zinc, but the section on the analysis of zinc-base alloys is too sketchy and contains less information than is found in B.S. 1005. Confirmatory tests and both gravimetric and volumetric methods for determining cadmium are given, but there is no treatment of physico-chemical methods of determining cadmium and zinc other than a brief example of the polarographic determination of cadmium in copper alloys. A lengthy bibliography follows the section of physico-chemical methods of analysis, but elsewhere no references are given.—ZDA. 7813

2.3.5, 2.4.3, 2.1.1

Measure Corrosion Rates in Soil Without Weighing the Metal. *Plant,* **7,** No. 2, 58-59 (1953) February.

Measurement electrically without excavation, visual inspection, or weighing the metal. Advantages of the electrical method are: 1. present corrosion rates are measured, which is probably more important than past corrosion history; 2. corrosion products, which often inhibit further corrosion, need not be removed; and 3. elemination of cleaning errors.

Corrosion loss is determined from the equation

$$i_o = \frac{Ip \cdot Iq}{Ip + Iq}$$

where i_o is the corrosion current and Ip and Iq are the external d-c currents applied cathodically and anodically, respectively, that are required to reduce the corrosion current to zero. The values of Ip and Iq are obtained from the changes in slope of the cathodic and anodic polarization curves.

In laboratory tests, weighed steel specimens, differentially aerated, were exposed to five corrosive soils of pH 2.2-9.6. Corrosion losses calculated from the theoretical equation differed only by about 4% on the average from those obtained by direct weighing.—PDA. 7825

2.3.5, 5.8.1

Electrical Polarization and Its Utilization for Evaluating Inhibitors. (In Italian). G. Bombara. *Riv. Combustibili,* **7,** No. 9, 527-546 (1953) September.

The most general cause of corrosion is electrochemical attack of a metallic surface that is anodic to its surroundings. By using the metal in question as the anode in a standard cell and varying an external resistance from open to short circuit, a polarization curve is obtained which gives a complete electrochemical picture of the behavior of the metal. By adding a known percentage of an inhibitor to the solution in the standard cell, its effect on the polarization curve and thus on the corrosion behavior can be measured and compared with other inhibitors. 7690

2.3.6

(Measuring) Corrosion-Resistance. *Metal Ind.,* **83,** No. 19, 386 (1953).

In a new method of measuring corrosion-resistance developed at the U. S. National Bureau of Standards, specimens are ground and polished to optical flatness and immersed to half their depth in the desired corrosive solution. After a lapse of time they are withdrawn, rinsed and dried, and covered with an optical flat piece of quartz. Using a conventional interferometric viewing apparatus of the Pulfrich type and an unfiltered helium lamp for illumination, the displacement of the optical interference fringes at the level-of-solution line is observed. This displacement gives a measure of the corrosion attack. Sometimes the solution causes swelling of the specimen, and the lateral shift is then in the opposite direction.—MA. 7824

2.3.6, 1.6

Introduction of Electron Microscopy. C. E. Hall. Book, 1953, 450 pp. McGraw-Hill Publishing Co., Ltd., London.

A fairly detailed account of the principles on which electron microscopy and the lens actions are based. The way in which the image arises and the effect of lens operations are considered as are other image faults. The set up of an electron microscope is discussed and one chapter gives details of various commercial types. A long chapter on specimen methods for electron microscopy is included and a number of examples are shown.—BNF. 7704

2.3.6, 6.5

An Interferometric Procedure Applied to the Study of the Chemical Durability of Silicates, Enamels, and Metals. Robert G. Pike and Donald Hubbard. *J. Research Nat. Bur. Stand.,* **50,** No. 2, 87-93 (1953).

The method used is to immerse one-half of a ground flat specimen in a solution of known pH, covered with an oil layer to prevent water evaporation. After the specimen has been held at 80°C. for fixed times, the surface height in the exposed portion, relative to the unexposed surface, is found by means of a Pulfrich interferometer. In the tests on metals, cold rolled steel, aluminum, copper, brass, silver, and platinum were used. These all had good corrosion-resistance for pH 6-10, but there was a definite attack on all except platinum below pH 6. Aluminum, treated at pH 10.2, gave a hard black coating, with no dimensional change observable. The oxide film is thus presumably <30 Å thick, this being the limit of resolution of the method. The method provides a convenient and rapid way of ascertaining corrosion-resistance under widely differing conditions.—MA. 7806

2.3.7, 2.1.1, 5.4.1

Two New Methods Allowing the Determination of the Index and the Thickness of a Thin Transparent Film. F. Abeles. *Compt. Rend.,* **236,** 1412-1413 (1953); *Sci. Abs., A,* **56,** No. 670, 849 (1953).

The (refractive) index and thickness of a thin transparent film deposited on a transparent base can be derived by measuring the transmission factor of the parallel and perpendicular polarized beams relative to an incident vibration, polarized parallel and perpendicular to the plane of incidence, the two measurements being effected at the same angle of incidence. Mathematical relations are derived so that constants can be obtained using different angles of incidence. The effect of errors of measurements of the values calculated is discussed. The method has been applied successfully to titanium oxide layers.—RPI. 7870

2.3.7, 5.3.2, 2.4.3

A Porosity Test for Electrodeposits on Zinc-Base Die Castings. H. K. Lut-

WAK. *Bull. Inst. Metal Finishing*, **3**, No. 2, 85-90 (1953) Summer.

In this new method of determining the porosity of metal coatings on zinc alloy die castings, a test solution consisting of ammonium chloride and potassium ferrocyanide is used. The ammonium chloride corrodes the zinc at the bottom of pores and keeps the zinc in solution; the ferrocyanide forms a white, insoluble compound with the dissolved zinc. Irregularly shaped articles are first given a thin coat of shellac and are then completely immersed in the test solution; white spots grow on the sites of pores in the coating. For testing flat, cylindrical or conical surfaces, the solution may be applied by means of absorbent paper. The white compound shows up well on black paper; alternatively, if the compound is converted to suitably colored salts, white paper can be used.—ZDA. 7761

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1, 1.2.2

Economics of Cathodic Protection. RAY M. WAINWRIGHT. *Gas*, **30**, 48-53 (1954) April.

Basic aspects of correct economic analysis. Includes elementary principles of interest rates, annuities, sinking funds and other types of transactions involving money. Methods of determining costs and of making economic comparisons. Graphs. 3 references.—MR. 7606

5.2.1, 2.3.5

Current Drainage Survey for Cathodic Protection. H. M. POWELL. *Corrosion Prevention & Control*, **1**, No. 2, 100-101 (1954) April.

Determination of total current requirements to maintain all parts of the structure surface under consideration is necessary in designing a cathodic protection installation. Discussion of current drainage testing, consisting virtually of the installation of a temporary cathodic protection system, is included. A source of supply of suitable D. C. current and a temporary ground-bed are essential for the drainage test. From data obtained from the tests, a permanent installation can be designed.—INCO. 7578

5.2.1, 3.6.9

Minimizing Damage to Adjacent Structures in Urban Cathodic Protection Installations. D. T. ROSSELLE. *Corrosion*, **10**, No. 6, 192-194 (1954) June.

Examples are given of methods whereby structures adjacent to underground plant put under cathodic protection can be protected from damage as a result of picking up current. Bonding, with proper consideration to the reason for the bond, is urged. Bonds should be calibrated and test leads provided for future investigation of changes that may take place in potentials. An example is given of an instance in which cross-bonding did not provide sufficient protection for a telephone cable adjacent to a pipe line put under protection.

Damage to adjacent structures may be minimized by distributing anodes parallel to the structure to be protected and by using as many small rectifiers as is economically feasible.

The author believes cooperative committees, such as are in operation in numerous urban areas of the country, are the real answer to cathodic protection interference problems. Advantages of cooperative protection of all underground structures in an area are emphasized. 7579

5.2.1, 3.6.9, 7.7

Some Experiences With Cathodic Protection in Chicago. L. M. PLYM. *Corrosion*, **10**, No. 7, 213-214 (1954) July.

Removal of street car rails in parts of Chicago has necessitated the use of cathodic protection for many sections of lead sheathed telephone cables. For each of several situations data have been collected as follows: 1. Type of power supply. 2. Design of ground bed. 3. Current and voltage requirements. 4. Cable sheath potentials. 5. Amount of cable protected and 6. First cost and power cost. 7594

5.2.1, 8.2.2, 7.4.2

Cathodic Protection in Florida Power and Light Company's Generating Plants. JOSEPH B. PRIME, JR. *Corrosion*, **10**, No. 5, 165-168 (1954) May.

Cathodic protection of intake structures and seawater cooled condensers at plants of Florida Power and Light Company has proved practical and economical during the past five years. Systems involving both rectifier current and galvanic current from sacrificial anodes are being employed. Experience at the plants indicates that a combination of copper screen and black iron for moving racks gives better service under cathodic protection. Inspection of protected structures shows substantial and satisfactory protection is being obtained in the tidal zone. Insulation of intake structures from reinforcing steel in concrete is recommended to permit application of greater densities without chance of cracking concrete through accelerated rusting of reinforcement. Experiments with con-

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densers prove insulation of condenser tubes from water boxes is desirable. Tests with three condensers showed the value of insulation and cathodic protection. Author recommends attention to cathodic protection needs in designing structures. 7597

5.2.2, 2.3.5, 3.7.2, 6.4.4

Cathodic Protection—Influence of the Composition of Magnesium Anodes on Their Efficiency. M. OUDEMAN. Paper before Symp. on Cathodic Protection, Corrosion Group, Soc. of Chem. Ind., London, Nov. 13, 1953. *Chemistry & Industry*, No. 8, 210 (1954) Feb. 20.

Some magnesium anodes used in the protection of a buried pipeline were found abnormally inefficient, being excessively corroded and yielding small currents. Examination showed them to differ considerably in composition from anodes of satisfactory performance, by having high contents of aluminum (12%) and of general impurities, and suggested that they had undergone some intercrystalline corrosion. A laboratory method for assessment of anode efficiency was devised. Test material was connected to steel, immersed in aerated sea-water, through a variable resistance used to keep the anode current density at 300 milliamps, per sq. ft. Method was found capable of revealing inefficient anode material and was used to study variation of anode efficiency with temperature.—INCO. 7675

5.2.2, 3.7.2, 6.4.4

Effect of Alloying and Impurity Elements in Magnesium Alloy Cast Anodes. H. A. ROBINSON AND P. F. GEORGE. *Corrosion*, **10**, No. 6, 182-188 (1954) June.

Data from extensive laboratory anode efficiency tests and supporting field tests illustrate the need for low impurity levels in magnesium alloy (6% aluminum—3% zinc) cast anodes. Data are presented which show the detrimental effects of the impurities copper, nickel, iron, lead and tin; the beneficial effect of manganese in counteracting to some extent the effects of iron and perhaps copper; the absence of any pronounced effect of aluminum and zinc in the amounts specified in this alloy; and the inertness of small additions of beryllium on the anode efficiency. 7598

5.2.3

Contribution to "Cathodic Corrosion Protection." (In German). WOLFGANG THURY. *Werkstoffe und Korrosion*, **5**, No. 3, 84-87 (1954) March.

After discussing fundamental terms and definitions of cathodic corrosion protection, the author shows some interesting applications of the galvanic method for cathodic corrosion prevention. The use of outside current supplies in conjunction with an auxiliary insoluble anode is the topic of the present report. Tests with aluminum and iron showed that good results for corrosion protection are obtained with small amounts of electric energy. The protection for aluminum, however, is limited by the so-called "cathodic corrosion" in which the cathode is partially dissolved. Different investigations made in obvious that cathodic corrosion protection of aluminum in neutral or alkaline solutions containing alkali or alkaline-earth ions is difficult, or even impossible. In moderately acid solutions cathodic protection of aluminum is successfully used. Current required per square meter and per year is used to calculate cost. Tables, 16 references. 7605

5.2.3, 4.6.4, 7.4.2

The Application of Cathodic Protection to Box-Coolers In Refinery. H. SHIGENO. *Corrosion Engineering* (Japan), **3**, No. 1, 28-32 (1954) Feb.

A cathodic protection system with external source has been installed to four open-type box-coolers in the Kawasaki Refinery of the Showa Petroleum Co. Direct currents of 2.0-3.0 volts supplied from a selenium rectifier were applied to the surfaces of steel pipes and tanks through the steel anodes immersed vertically into the cooling sea water. As the result of determining the potential differences between protected steel surfaces and adjacent water, it was confirmed that the potential distribution was fairly good, showing in every part far more negative potential than —0.77 volt referred to saturated calomel electrode. These potentials moved considerably to the negative side with the lapse of time as a result of increasing cathodic polarization. As a basic date for design, the adequate protecting current was estimated to be 0.1 ampere per sq. meter of protected surface.—JSPS. 7693

5.2.3, 7.10

A Fundamental Test on Cathodic Protection in Shiogama Port. I. ENDO, M. YAMASHITA AND T. KAKEI *Corrosion Engineering* (Japan), **3**, No. 2, 31-33 (1954) April.

A fundamental test on cathodic protection of a steel pier in Shiogama Port was carried out. From the test it was found that 1. the current required for protection was about 100 amps against 2,000 sq. meters of the surface of steel piles and sheet piles, 2. a current from one direct current source unit with six magnetite anodes buried or hung under the pier fully protected 24 steel piles, and 3. the current distribution was very satisfactory.—JSPS. 7683

5.3 Metallic Coatings

5.3.4

Electroless Nickel Barrel Plating. H. J. WEST. *Metal Finishing*, **52**, No. 3, 64 (1954) March.

Article presents the results obtained with electroless barrel nickel plating in actual commercial production, explaining and outlining the exact procedure, type of equipment and formula actually in use.—INCO. 7634

5.3.4

Crack-Free Chromium Deposits. H. W. DETTNER. *Metelloberflache*, **6**, B69-B73 (1954) May.

Review of methods of obtaining heavy chromium deposits with particular reference to method giving crack-free deposits. Heavy crack-free deposits were tested for corrosion resistance. Effect of raising plating bath temperature on corrosion resistance of coating is discussed. Improved behavior was obtained irrespective whether intermediate layers of copper and/or nickel are used. Improved corrosion behavior observed in these deposits is due to the crack-free nature of the deposits. Disadvantage of crack-free deposits is the lower hardness.—INCO. 7623

5.3.4

Nickel Plating Troubles and Cures. O. A. STOCKER. (United Chromium Inc.) A. KORBELAK AND S. A. CARRANO. (Boston Coll.) *Plating*, **41**, 491-496 (1954) May.

Nickel plating trouble shooting chart is subdivided into 11 categories, including lack of adhesion (peeling), deposit lacks ductility, deposit is dull (bright nickel baths), deposit is dark, streaky deposits, spotty deposits, deposit dark in recesses, poor throwing power and poor coverage, burnt edges or frosty plate, pitting, and rough deposits. Possible sources of trouble and suggested cures are given in each section.—INCO. 7620

5.3.4, 1.6

Chromium Plating. P. MORISSET, J. W. OSWALD, C. R. DRAPER, & R. PINNER. Book, 1954, 611 pp. Robert Draper Ltd.

Discusses all aspects of the production, properties and applications of chromium electrodeposits as well as polishing, grinding, and machining, copper and nickel plating, racking, testing and inspection of deposits, control and analysis of solutions, health hazards, coating and waste disposal. Important feature is an extensive bibliography to December, 1953.—INCO. 7612

5.3.4, 5.4.8

Porosity of Sprayed Coatings: Part III: Impregnation and Organic Finishing of Sprayed Coatings. D. DE PAAUW. *Electroplating and Metal Finishing*, **7**, No. 1, 35-38 (1954) Jan.; *Metal Spraying*, **4**, 35-38 (1954) Jan.

Of greater value than the mechanical methods used to improve the corrosion resistance of sprayed coatings are processes by means of which the pores of the sprayed coating are sealed by impregnation with varnish, lacquer, ozokerite wax mixed with liquid paraffin, phenol formaldehyde resin solutions in acetone, inorganic sealing compounds, etc. While the impregnation processes are designed to improve the properties of the sprayed coatings by impregnation alone, an increasing amount of sprayed work is painted by conventional methods, which affords a very effective protection especially for structural steel. In recent tests 4,500 steel panels have been coated with between 0.003 and 0.015 in. zinc or aluminum plus different sealers and top coats. The choice of paint must be considered in relation to the nature of the sprayed metal underneath. Lead-pigmented paints must be avoided on aluminum. The paint should have good flow properties and must be able to exclude water from the metal. Different paint compositions are investigated with regard to their application.—ALL 7677

5.3.4, 6.3.19

Vacuum Metallizing Reduces Finishing Costs. *Materials & Methods*, **39**, No. 2, 103-104 (1954) Feb.

A pictorial story of how pressure die cast zinc products are bright-finished with aluminum, using the vacuum deposition technique at the rate of 20,000 per 8-hour day in a single 48 in. metallizing unit. The finish withstands 250 hours of salt spray without breakdown and costs one-sixth that of electroplating, mainly because the parts need no buffing or polishing. The process consists of degreasing, a phosphate dip, lacquering, metallizing, and a second protective lacquering. 7591

5.4 Non-Metallic Coatings and Paints

5.4.2, 2.3.7, 3.5.8

Flexure and Fracture of Vitreous Enameled Steel Strips. C. J. RODMAN AND

F. J. SHOLLENBERGER. Alliance Ware Inc. Paper before Am. Ceramic Soc., 55th Ann. Mtg., April, 1953. *Bull. Am. Ceramic Soc.*, **33**, No. 4, 105-107 (1954) April.

An investigation of the strength of varying steel gage thicknesses as used in the manufacture of steel sanitary ware and the accompanying effect of enamel coatings thereon was made. A new sensitive apparatus was developed to determine the progressively increasing loads (stress) and the corresponding deflections (strain) of enameling grade steel used. In the case of porcelain enamel on steel, the stress-strain curves show that the added strength is not in proportion to the thickness of the enamel but due to the bonding of the enamel to steel; the strength has increased approximately as the cube of the sum of the steel thickness and one half the enamel thickness.—INCO. 7646

5.4.2, 3.5.8

Effect of Ceramic Coatings on Fatigue Strength of Metal. W. J. PLANKENHORN. University of Illinois. Paper before Am. Ceramic Soc., 55th Ann. Mtg., April 28, 1953, New York. *J. Am. Ceramic Soc.*, **37**, No. 6, 281-288 (1954) June 1.

The fatigue strength of enameling iron before and after pickling and as coated with three different ceramic coatings and with 1 oil-mixed paint was determined. All tests were made on repeatedly-bending machines. A comparison of the stress vs. cycle curves for the metal alone and for the coated metal showed that ceramic coatings noticeably improved the fatigue strength and the fatigue life at stresses above the endurance limit. Ceramic coatings contained 0.5% nickel oxide. Fatigue data are presented. 17 references.—INCO. 7589

5.4.5, 1.6, 5.9.1

Steel Structures Painting Manual. Volume I: Good Painting Practice. JOSEPH BIGOS, Editor. 423 pages, 1954. Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh 13, Pennsylvania.

This is a compilation of recommendations on painting collected under the auspices of the Steel Structures Painting Council's 19 member organizations. Each of the eighteen chapters is authored by a person selected for his knowledge of the subject. Chapters are liberally illustrated and referenced.

Subject headings are: Simplified Theory of Corrosion, Mechanical Surface Preparation, Chemical Surface Preparation, Practical Aspects, Use and Application of Paints, Inspection, Quality Control of Paints, Comparative Costs, Shop Painting of Steel in Fabricating Plants, Painting of Railroad Bridges and Structures, Paintnig of Steel Vessels for Salt Water Service, Painting of Steel Vessels for Fresh Water Service, Painting of Steel Tanks, Painting of Steel in Hydraulic Structures, Protection of Pipelines and Other Underground Structures, Water and Sewage Works Structures, Maintenance Painting of Steel and Coke Oven Plants, Petroleum Refineries, Chemical Plants, Color in Industrial Plants, Metallizing and Causes and Prevention of Paint Failure. 7617

5.4.5, 2.2.2, 6.4.2

Priming Paints for Light Alloys. J. G. RIGG AND E. W. SKERREY. *Paint Manuf.*, **24**, No. 3, 75-84 (1954) March.

Results are given of 3½ years of testing various paint primers on aluminum and magnesium alloys and mild steel in rural, industrial and marine atmosphere, to determine the relative protection values. Comparison was simplified by the use of four pigments. Of these, red lead was found to be the most harmful, especially in marine atmospheres; this corrosive effect was much more severe on magnesium and its alloys than on aluminum and its alloys. Zinc chromate and zinc tetroxychromate primers are the most suitable for use on light metals under very severe corrosive conditions, and are also appropriate for ferrous metals—especially in composite structures of steel and light alloys. Iron oxide primers are satisfactory for both light and ferrous metals where corrosive conditions are not too severe. As a medium for aluminum finishing paints the use of alkyd-linseed stand oil varnish (D.T.D. 260A) was found to be preferable to a cellulose (D.T.D. 63A) top coat. An analysis is given of the metals used for these tests and results of the whole investigation are summarized in tabular form.—ALL. 7655

5.4.5, 2.2.5

Laboratory and Plant Evaluations of Liquid Neoprene Coatings. R. B. SEYMOUR. *Corrosion*, **10**, No. 4, 116-121 (1954) April.

Liquid neoprene, among the coatings commercially available today, appears to be closest to the ideal coating, the author believes. The characteristics of several compositions of neoprene are given, application and curing techniques discussed, resistance to certain chemicals itemized and conformity with military

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and industrial standards compared. Superiorty of Type KNR over certain other compounds of neoprene is described and explained.

The author recommends on-the-job compounds as superior to one-part compounds. Specifications for various kinds of neoprene formulations are given, together with an explanation of fillers, applications and compounding techniques.

Numerous case histories of successful application of neoprene to protect plant against various corrosive environments are listed. 7599

5.4.5, 5.8.4

The Protective Action of Pigments on Steel. M. J. PRYOR. *J. Electrochem. Soc.*, **101,** No. 3, 141-148 (1954) March.

The action of aqueous extracts from litharge, metallic lead, red lead, basic lead carbonate, zinc, and zinc oxide on the corrosion of steel was investigated. Litharge extracts inhibit corrosion of steel completely, those from metallic lead and red lead for a short period. Extracts from basic lead carbonate, zinc and zinc oxide had no protective action. Protective properties of the decanted extracts were in the order of their reserve alkalinities. Litharge, metallic lead and red lead extracts protected only when they contained dissolved air; when de-aerated, they attacked steel slowly. The passivity film formed in litharge extracts was composed largely of γ-Fe_2O_3, no lead compounds being detected. Lead in the litharge extracts is present partly in the ionic form, possibly as $Pb(OH)^+$ ions whereas in extracts from metallic lead it is present mainly as massive and colloidal lead hydroxide. 24 references.—EL. 7665

5.4.7, 8.9.3

Internal Coating of Pipe in Place. M. B. GROVE. *Corrosion,* **10,** No. 5, 142-146 (1954) May; *Oil Gas J.,* **52,** No. 37, 109-110 (1954) Jan. 18.

Procedures and results of coating internally several miles of old aluminum, steel and new steel pipe are given. The method involves scraping corrosion products from inside old pipe, descaling and drying. Coating is applied when two plugs between which coating has been poured are moved through the pipe by air pressure. Drying by air injection or aspiration follows. Economics of the lining operation are reported to be good although perfect results were not obtained with badly corroded steel pipe. Adhesion of the coating is the critical problem, even small amounts of water being conducive to separation. Coating of new steel lines is facilitated by proper design. The author suggests rigid inspection at every phase of the cleaning, drying and coating operation. At least 5 mils' thickness is recommended, this to be obtained by multiple coats, if necessary. When desiccants are used in the drying operation some means of determining when the desiccant is saturated should be employed. Better cleaning is needed, especially to remove sulfides. 7671

5.9 Surface Treatment

5.9.2, 5.8.2

A Study of Pickling Inhibitors. First Report: The Effects of Acid Pickling Inhibitors on the Electrode Potentials of Mild Steel. A. ADACHI. *J. Japan Inst. Metals,* **18,** No. 1, 9-11 (1954) Jan.

The action of the acid pickling inhibitors such as Restin, Rodine No. 77 and Xylidine were measured. Potential of mild steel was measured in sulfuric acid with and without inhibitors. The steady state potentials were measured by a potentiometer and original unsteady state potentials were measured by an oscillograph. The adsorbed film of inhibitors on mild steel could not be removed in acid and neutral salt solution. The desorption in alkaline solution was shown to be nearly perfect but it is not so perfect as to achieve a fine hot galvanized surface.—JSPS. 7631

5.9.2, 8.2.2, 4.6.4, 5.2.2

Remove Scale With Chemicals. J. P. WARREN. Dow Chemical Co. *Southern Power and Ind.,* **72,** No. 5, 70-71, 104 (1954) May.

In three power plants of the Texas Division of the Dow Chemical Co., chemical removal of scale is standard practice. Method results in cleaner surfaces, shorter outages and reduced costs. Cooling water for the plants is drawn from the Gulf of Mexico and is heavily laden with microscopic organisms. Chemical cleaning effectively removes the iron bacteria and scale from water boxes laid down by salt water corrosion and scale on graphitized cast iron water boxes. Graphitization problem was eliminated by cathodic protection with magnesium anodes. Illustrations.—INCO. 7628

5.9.2, 8.4.3, 8.8.1

Three "Musts" in Chemical Cleaning. D. P. THORNTON, JR. *Petroleum Processing,* **9,** No. 3, 359-363 (1954) March.

Discussion of three requirements in chemical cleaning which are: identification of the type of deposit to be removed, selection of correct solvent and inhibitor, and use of the most practical cleaning technique. Eight cases of chemical cleaning in refineries, natural gasoline and petrochemical plants are briefly discussed. Table compares attack rate of inhibited and raw hydrochloric acid on various metals and alloys, including steel, cast iron and Admiralty.—INCO. 7586

5.9.4

Contribution to the Theory of Electropolishing. C. WAGNER. *J. Electrochem. Soc.,* **101,** No. 5, 225-228 (1954).

An ideal electropolishing process is characterized by a plateau of the current density-potential curve corresponding to the maximum diffusion rate of an acceptor for metal ions toward the anode. Such a process is amendable to a quantitative theoretical analysis. Formulae are derived for decrease of surface roughness as a function of the recess of the average surface, amount of metal dissolved per unit surface area, and product of current density and time.—EL. 7584

5.9.4, 2.3.4

Determination of the Thickness of Anodic Coatings by Gravimetric Method. A. PRATI. *Alluminio,* **22,** No. 1, 7-22 (1954) January.

Numerous methods have been invented for determining the thickness of anodic coatings which is a fundamental factor with regard to corrosion- and abrasion-resistance. The gravimetric method which is the topic of the present report, is based on the solubility of aluminum-oxide in a boiling mixture of chromic anhydride (2%) and phosphoric acid (3.5%), whereas aluminum and its alloys are not attacked by this mixture. The weight of the dissolved oxide layer is then determined and the values, in connection with density and surface dimensions, converted into thickness of the layer. To control the accuracy of this method a statistical analysis has been made of results obtained from a systematic series of determinations carried out on samples produced in controlled conditions. The results of the tests showed that the precision of the described method—as traced by statistical analysis—is defined by a measuring error of 0.28μ. However, the accuracy of the method is somewhat limited.—ALL. 7663

5.9.4, 6.4.2

The Anodic Behaviour of Aluminium and Aluminium-Magnesium Alloys in Sulfuric Acid and Sodium-Sulphate Solutions. (In German). WILLI MACHU AND M. KAMAL HUSSEIN. *Werkstoffe u. Korrosion,* **5,** No. 2, 49-54 (1954) February.

As the porosity of aluminum-oxide films could only be estimated up to the present, it has been the aim of the work described here to determine quantitatively the value for the porosity. The studies were carried out on an aluminum-magnesium-alloy containing 14.19% magnesium and on spectro-chemically pure aluminum. To produce pure aluminum surfaces the oxide-film was removed from the testing material with diluted sulfuric acid and sodium-sulfide solutions of different concentrations as eletcrolyte. Cathodic polarization had a slightly loosening and activating effect on the natural oxide film. However, rapid passivation always followed this activation. Higher concentrated hydrochloric acid and caustic soda dissolved the oxide layer but did not permit anodic passivation in these solutions. Activation was also possible in sulfuric acid containing chlorine ions, but in this solution passivation by chemical reaction of the electrolyte also occurred immediately after the current was switched off. The porosity of the natural oxide film was 10^{-4} to 10^{-5}sq.cm./sq.cm. By activation a maximum of 10^{-3}sq.cm./sq.cm. could be obtained.—ALL. 7637

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.2, 3.7.2, 3.2.2

Estimation and Influence of the Gaseous Elements in Cast Iron. L. W. L. SMITH, B. B. BACH and J. V. DAWSON. Paper before Inst. Brit. Foundrymen, Birmingham Branch. *Foundry Trade J.;* **96;** Nos. 1957, 1958 & 1959; 233-238; 275-280; 303-306, disc. 306-309 (1954) Mar. 4, Mar. 11, Mar. 18.

Differing behavior of cast irons of apparently similar composition has often been attributed to the effects of gases in the iron. This paper attempts to clarify the situation by reviewing work which indicates a correlation between the property of the iron and gaseous elements. Effects of oxygen, hydrogen, nitrogen, and influence of nitride-forming elements are discussed. Tables, graphs, photomicrographs, and 28 references.—INCO. 7648

6.2.3, 3.5.9, 5.3.2

The Efficiency of Some Protective Treatments in Preventing the Oxidation of Mild Steel at High Temperatures. A. H. SULLY, E. A. BRANDES and R. H. BROWN. *Metallurgia,* **49,** No. 294, 165-168 (1954) April.

Mild steel can be used at elevated tem-

peratures provided that oxidation is prevented. Results of an investigation into the relative effectiveness of chromizing, aluminum coating and enamelling in providing protection against oxidation when the steel is heated to 700°C. for 1000 hours, are given. Shorter exposures at 800 and 900°C. are also discussed. Chromizing was the most effective treatment. Tables and graphs.—INCO. **7622**

6.2.3, 3.7.2

Rare Earth Additions Affect Surface Quality of Low Carbon Steel. J. V. RUSSELL. Republic Steel Corp. Paper before AIME Nat'l. O. H. Steel Conf., Chicago, April 5-7, 1954. *J. Metals* (Trans. AIME), **6**, No. 4, 438-442 (1954) April.

Additions of rare earth metals reduce effectively the sulfur content of steel to which they are added either in the ladle or the mold. The efficiency of this removal depends on the amount of sulfur present and increases with increasing sulfur. Rare earth oxides showed very little effect on sulfur either as ladle or mold additions. Improvements in surface quality which did not result from rare earth additions appeared to be due in large part to increase of low manganese-sulfur ratio. Where this ratio was high, no improvement resulted. Addition of rare earth metals to aluminum killed steel in amounts greater than 2 lb. per ton resulted in a hot short condition more severe than that due to aluminum alone. This hot shortness resulted in hot tears during rolling which increased in severity with the amount of rare earth metal additions. Rare earth oxides did not have this effect but instead reduced the effect of aluminum, undoubted by oxidation of it.—INCO. **7593**

6.2.3, 6.2.4

Short-Time Tension and Creep-Rupture Properties of Hardened 1040, 4340, and Nickel-Chromium-Molybdenum-Vanadium Steels up to 1000°F. G. V. SMITH and W. B. SEENS. Paper before ASTM, 57th Ann. Mtg., June 13-18, 1954. Am. Soc. Testing Materials, Preprint No. 78, 1954, 10 pp.

Short-time tensile properties at 80, 500, 700, 850, and 1000°F. and creep-rupture properties at 850 and 1000°F. are reported for 1040, 4340, and nickel-chromium-molybdenum-vanadium (0.40%C.) steels heat treated to a tensile strength of 150,000 psi. at room temperature. The 1040 steel was also tested in creep-rupture at 500 and 700°F.—INCO. **7608**

6.2.3, 4.3.3

Hydrothermal Synthesis of Quartz Crystals. A. C. WALKER. Bell Telephone Labs., Inc. Paper before Am. Ceram. Soc., 44th Ann. Mtg., Pittsburgh, April 29, 1952. *J. Am. Ceram. Soc.*, **36**, No. 8, 250-256 (1953) Aug. 1.

Many of the difficulties in the growing of large single crystals of quartz were due to corrosion of steel in alkaline solution. This was an unexpected problem, since in high-pressure steam boilers alkali is added in small amounts to prevent corrosion of the boiler tubes. Such corrosion was shown to be responsible for the appearance of electrical twinning on the growing faces of the quartz crystals. Graphs and 13 references.—INCO. **7368**

6.2.4

American Applications of Boron and Other Low-Alloy Steels. H. B. KNOWLTON. Internatl. Harvester Co. Paper be-

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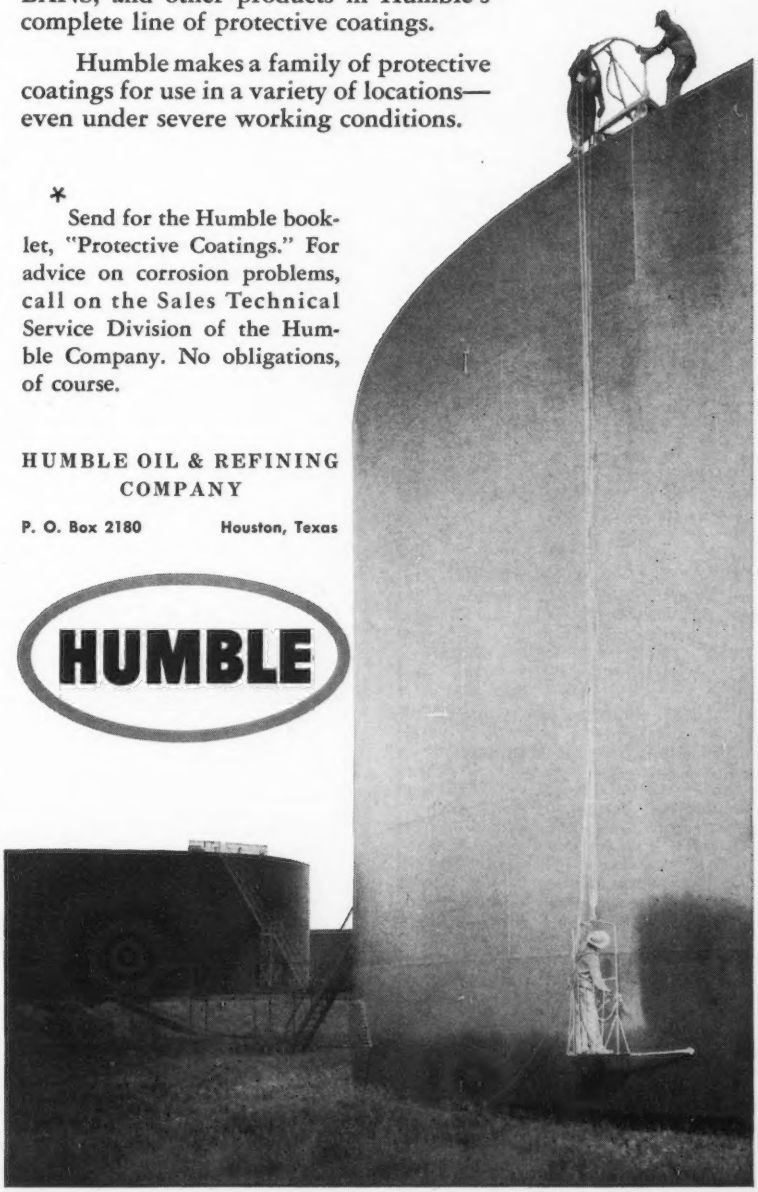

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fore Iron & Steel Inst., Special Mtg. on Boron in Steel, London, April 20, 1953. *J. Iron Steel Inst.*, **176**, Pt. 2, 187-216 (1954) Feb.

In the U. S., to conserve nickel and molybdenum about 8-10% of the tonnage of low-alloy constructional steels were converted to lower-alloy steels containing boron, with satisfactory results. No failures attributable to the steel were reported. During the last war, U. S. industry created a series of low-alloy steels on the basis of duplicating the hardenability of ones previously used. These gave satisfactory performance in most cases. Boron steels have shown adequate toughness for safe performance of heat-treated parts, such as light and heavy coil and leaf springs and axles up to at least 3 in. dia., for which they were tried. Tests of finished parts have shown as good fatigue strength for boron steels as for other alloy steels of equivalent hardenability. Boron steels have not been so satisfactory for case hardening, owing to the difference of the effect of hardenability on the case and core. Appendix discusses principles for the application of boron steels. Tabulations of chemical composition give nickel content. Discussion, graphs, tables, 27 references.—INCO. 7253

6.2.4, 3.7.2

Vanadium as Replacement for Molybdenum in Low-Alloy Steels. C. L. M. COTTRELL AND B. J. BRADSTREET. *British Welding J.*, **1**, No. 2, 82-86 (1954) Feb.

Substitution of vanadium for molybdenum in certain low-alloy steels, containing 0.10-0.83% nickel, has resulted in a much lower transition temperature combined with much higher values of proof stress (0.02%) without adversely affecting the weldability of the steels. Results apply to plates normalized under conditions equivalent to 1½-in. thick sections. Similar improved properties could probably be obtained with molybdenum steels by tempering them at about 600°C. Graphs, tables, photomicrographs and 9 references.—INCO. 7227

6.2.4, 3.7.3

Weldability of Manganese-Molybdenum Steel Related to Properties of the Heat-Affected Zone. C. L. M. COTTRELL. *Brit. Welding J.*, **1**, No. 4, 177-186 (1954) April.

The mechanical properties of a commercial manganese-molybdenum steel were studied under conditions simulating the heat-affected zone adjacent to metal-arc welds. Various cooling rates were used, covering the range which occurs in normal metal-arc welding. The steel was thermally heated, with and without previous supersaturation with hydrogen. Mechanical tests comprised impact, slow, and dead-load tensile tests. The best correlation between mechanical-test results and weldability was obtained in the dead-load tensile test. Conditions producing hardzone cracks in welding gave a brittle-type fracture at low stress in this test, the results of which indicate behavior of the material during welding. The results are discussed in relation to the transformation-characteristics of the weld-affected zone and its liability to hard-zone cracking. The steel tested contained 0.13% nickel, 1.3% manganese, .023% phosphorus, .1% chromium, .25% molybdenum, .2 ml./100g. of hydrogen. Mechanism for initiation of these cracks is suggested. Tables, graphs, photomicrographs. 15 references.—INCO. 7526

6.2.5

Way to Save Nickel. *Steel*, **134**, No. 7, 122 (1954) Feb. 15.

20% chromium — 9% nickel alloy, designated as the HF grade, can substitute for 26% chromium—12% nickel (HH grade) in the intermediate temperature range of 1200-1600°F. Mechanical properties are comparable to those of higher nickel heat resisting alloys. HF grade as-cast has satisfactory ductility; average elongation is about 30%. Sectional damper, used in a steel mill heating furnace, made of Thermalloy 30 (HF) alloy is illustrated.—INCO. 7246

6.2.5

Low Carbon Stainless Resists Intergranular Corrosion. R. E. PARET. *Iron Age*, **173**, No. 18, 132-134 (1954) May 6.

Low carbon stainless steels used in place of more familiar stainless grades offer a solution to some of the problems of intergranular corrosion. The lower carbon grades, types 304L and 316L, can be used to replace higher carbon types 304 and 316 in some cases. Compositions, including nickel content, are given. Carbide formation in lower carbon grades occurs so slowly that normal welding and stress relieving temperatures have no noticeable effect on corrosion resistance. Failure of parts too complex or too large for solution treating can be often avoided. Illustrations. INCO. 7581

6.2.5, 3.7.2

Chromium-Manganese Stainless Steels. J. L. EVERHART. *Materials & Methods*, **39**, No. 3, 92-94 (1954) March.

Continuing shortage of nickel is reviving interest in chromium-manganese stainless steels which have properties that compare favorably with those of chromium-nickel steels, such as 18:8. Carbon, nitrogen, manganese and copper in addition to nickel, promote the retention of austenite at room temperature, and it is possible to replace most of the nickel by using them. Addition of nitrogen to low manganese or nickel alloy increases the stability of the austenite. Austenitic steels stabilized by nitrogen include 18:8; 23% chromium, 5% nickel, 0.25% nitrogen; 20-22% chromium, 3.5% manganese, 3.5% nickel, 0.2% nitrogen; and 15% chromium, 15% maganese, 0.2% nitrogen. Steels briefly discussed include 15% chromium, 16.5% manganese, 1% nickel, 0.15% nitrogen and 0.10% carbon (TRC); 17% chromium, 6% manganese, 4% nickel, 0.15% nitrogen and 0.10% carbon; 18% chromium, 10% manganese, 4% nickel; and 16% chromium, 15% nickel, 6% manganese, 6% molybdenum. Two chromium-manganese stainless steels (19% chromium, 5.8% manganese, 8% nickel, 1.3% silicon, 0.6% titanium and 0.45% carbon; and 10% chromium, 18% manganese, 0.4% titanium, 0.8% silicon and less than 0.12% carbon) are used in Germany as welding rods. Illustrations, tables, 10 references.—INCO. 7619

6.2.5, 4.3.3, 3.2.3

Study on High Temperature Oxidation of Heat Resisting Steels. Part 1. T. AKUTAGAWA and T. FUJITA. *J. Iron Steel Inst.* (Japan), **40**, No. 1, 31-38 (1954) January.

The presence of a small quantity of the vanadium pentoxide or artificial ash, 2 mg (5mg) on specimens (15 x 20 x 1mm), was sufficient to increase the loss of metal from 10 to 50 times in 100 hours. It was found that this attack was accelerated with increasing quantity of vanadium pentoxide or artificial ash. Especially, Timken 16-25-6 alloy was attacked at 800-850°C. very severely.

It was presumed that when this alloy with 6% molybdenum was oxidized molybdenum trioxide appeared on its surface, and because molybdenum trioxide as well as vanadium pentoxide which had the very low melting point, fused together with the oxide film, the protecting action of the film was destroyed. In addition, molybdenum trioxide and vanadium pentoxide were the catalyser of oxidizing reactions, and thus the oxidation of the alloy was remarkably promoted.

To protect from vanadium attack, it would be necessary either to render vanadium pentoxide inert by calcium oxide, magnesium oxide etc. or to provide some new kind of protective layer such as ceramic coating etc. on the surface. It was found that when vanadium pentoxide was mixed with magnesium oxide or calcium oxide, the oxidizing reaction of materials was impeded at about 700°C.-800°C., and the materials covered with ceramic coating showed very excellent results against vanadium attack at 800°C.-900°C.—JSPS. 7695

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.4, 1.6

An investigation of Lamellar Structures and Minor Phases in Eleven Cobalt-Base Alloys Before and After Heat Treatment. J. W. WEETON and R. A. SIGNORELLI. Lewis Flight Propulsion Lab. Nat'l. Advisory Comm. Aeronaut., Tech. Note No. 3109, 50 pp., March, 1954.

Investigation of the occurrence and nature of lamellar structures and minor phases of cobalt-base high-temperature alloys, rolled, cast, and high-carbon Stellite 21, 422-19, X-63, 6059, 61, X-40, S-816, I-336, and J. Chemical analyses of alloys show they contain from 1-33% nickel. Minor phases TaC, NbC, Cr_3C_2, Cr_7C_3, $Cr_{23}C_6$, M_6C, Cr_2O_3 type oxides, spinels, and sigma were identified. Sigma phase patterns appeared strongest where large numbers of carbides were also present, indicating that carbide precipitation may facilitate sigma phase formation. Graphs, photomicrographs, tables and 16 references.—INCO. 7624

6.3 6, 3.7.3

Welding of 90/10 Copper-Nickel Alloy. G. R. PEASE AND T. E. KIHLGREN. Inco. Paper before AWS. Nat. Spring Mtg. Buffalo, May 4-7, 1954. *Welding J.* (N.Y.) **33**, No. 4, 329-338 (1954) April.

Data are presented which indicate the iron-bearing 90/10 copper-nickel alloys are satisfactorily welded by all the important fusion welding processes, including metal arc, inert-gas-shielded tungsten arc, inert-gas-shielded metal arc, submerged arc, and oxy-acetylene. Important variables are defined and suggested areas of usefulness are outlined for each of the methods. Data include preferred weld composition, effect of composition on strength and soundness, appropriate filler wire composition, and shielding gas and flux requirements. Response to silver brazing methods is treated briefly. Tables and 6 references. —INCO. 7583

6.3.6, 7.1

Application of Bronze Bearing Alloys. J. L. DUCHENE. American Brake Shoe Co. *Iron Steel Engr.*, **31**, No. 5, 92-97 (1954) May.

Factors to be considered in selection of bearing materials include fatigue strength, embeddability, conformability, seizure resistance, corrosion resistance and method of manufacture. Six general groups of alloys and their physical and bearing applications are considered. Typical of their respective groups are SAE 64, SAE 62, SAE 67, SAE 68, SAE 43 and a 4% silicon—1% manganese bronze. No mention of nickel bronzes is made since they are the basic alloy groups with nickel added to improve grain size and mechanical properties. Some actual applications, such as threaded bearings or screw down nuts, are reviewed. It is mentioned that up to 1% nickel added to SAE 64 makes this alloy fibrous and resistant to impact. Illustrations, photomicrographs.—INCO. 7626

6.3.9, 3.6.5

The Electrolytic Preparation of Molybdenum from Fused Salts. I. Electrolytic Studies. II. The Preparation of Reduced Molybdenum Halides. III. Studies of Electrode Potential. S. SENDEROFF and A. BRENNER. *J. Electrochem. Soc.*, **101**, No. 1, 16-27, 28-30, 31-38 (1954) Jan.

Part. I. Coherent or powder deposits of molybdenum (99.9+%) were obtained by electrolysis of K_3MoCl_6 dissolved in molten alkali halide mixtures. Part II. Methods for preparing K_3MoCl_6 and $(MoCl_2)_x$. Part III. The results of electrode potential measurements on mlybdenum and other metals in molten salts are presented. Brief account in *Iron Age*, **173**, No. 7, 166-169 (1954) Feb. 18.—BNF. 7600

6.3.9, 3.7.3, 5.3.2

The Pressure Welding of Molybdenum. A. R. Moss. *J. Inst. Metals*, **82**, Pt. 8, 374-378 (1954) April.

Construction and use of a controlled-atmosphere pressure-welding chamber are described. Conditions of temperature & deformation necessary to produce satisfactory welds in commercial sintered molybdenum sheet, in both argon and hydrogen atmospheres, were determined, and the effect of surface finish and cleanliness upon weldability studied. Welds were made at as low as 690°C; welding below the recrystallization temperature (approx. 1200° C.) is thus shown to be possible. By using inserts of various materials, the amount of deformation necessary to effect welding can be considerably reduced. Electro-deposited chromium, with which sound welds were produced, may prove especially valuable in this connection, since chromium and its alloys can also serve as oxidation-resistant coatings on molybdenum. The use of plated sheets to serve a dual purpose is therefore envisaged. Pressure welds having high strength and ductility at room temperature were produced on wrought cast molybdenum.—INCO. 7641

6.3.11, 3.8.4, 3.4.8, 3.4.6

Reaction of Silver with Aqueous Solutions of Cyanide and Oxygen. G. A. DEITZ AND J. HALPERN. *J. Metals* (Trans. AIME), **5**, No. 9, 1109-1116 (1953).

A study has been made of the dissolution of silver in sodium cyanide solution under oxygen pressure, over a wide range of conditions. The results obtained indicate that the predominant reaction which occurs is: $2Ag + 4CN^- + O_2 + 2H_2O \rightarrow 2Ag(CN)_2^- + H_2O_2 + 2OH^-$. The reaction rate is determined, principally, by the transport of the reactants to the silver surface; at low sodium cyanide concentrations and oxygen in excess, the transport of CN^- controls the rate; at higher CN^- concentrations, the transport of oxygen is the determining factor. Addition of calcium hydroxide or barium hydroxide lowers the rate of dissolution, owing to the formation of a deposit of calcium or barium peroxide on the silver surface. Nineteen references.—MA. 7429

6.3.13, 3.2.3, 5.9.4

The Formation of Anodic Oxide Films on Tantalum in Non-Aqueous Solutions. D. A. VERMILYEA. *Acta Metallurgica*, **2**, No. 3, 482-486 (1954) May.

Anodic films formed on tantalum in many non-aqueous solutions consist of 2 layers. Next to the metal there is a layer of tantalum pentoxide with the same characteristics as that of films formed in aqueous electrolytes, while between the tantalum pentoxide film and the solution there is a layer which is characteristic of the forming solution. Changes in the relative thicknesses of layers with formation rate, temperature, and forming solution result in a dependance of formation rate on the history of the film. During anodic oxidation tantalum ions move out through the tantalum pentoxide film to react with oxygen at the oxide-electrolyte interface.—INCO. 7585

6.3.13, 5.9.4, 3.7.3

The Effect of Metal Surface Condition on the Anodic Oxidation of Tantalum. D. A. VERMILYEA. *Acta Metallurgical*, **2**, No. 3, 476-481 (1954) May.

When tantalum is anodized at constant current, two different types of behavior are observed, depending on whether the metal surface is rough or polished. With polished sheets, an efficiency of 98% is obtained up to the spark voltage, and no change in the character of the oxide surface is observed. With rough sheet, apparent efficiencies greater than 100% are observed above a critical voltage depending on the nature of the original metal surface. Minute depressions are observed on the surface of the oxide film. The same behavior is observed for many different dilute aqueous solutions. Minute bubbles, formed at points of electrical breakdown, result in a decrease in effective area and hence an apparent efficiency greater than 100%. Depressions result when the oxide grows up around the bubbles. These effects are the result of a rough surface rather than the presence of impurities.—INCO. 7647

6.3.14

Tin and Tin Alloys. *Materials & Methods*, **37**, 127 (1953) March.

Tabulated information includes composition; physical and mechanical properties; corrosion resistance; and various uses.—MR. 7150

6.3. 14, 6.3.19, 5.9.4

Protective Treatments for Zinc and Tin. H. ANDERS. *Werkstoffe u. Korrosion*, **3**, No. 12, 460-461 (1953).

A description of chemical passivation treatments for zinc in chromate or ferrocyanide solutions, and of anodic treatment in ferrocyanide, ferricyanide, permanaganate, chromate or chromate-nitrate solution. Tin is passivated anodically in dilute ammonia, or acid sodium phosphate solution, and may be given a black film in phosphoric acid-ferricyanide solution.—E.L. 7492

6.3.15, 3.2.3, 3.8.4

Reaction of Oxygen and Nitrogen with Titanium from 700° to 1050°C. LEE S. RICHARDSON AND NICHOLAS J. GRANT. *Trans. Am. Inst. Min. Met. Engrs.*, **200**, No. 1, 69-70 (1954); in *J. Metals* (Trans. AIME), **6**, (1954).

Using a procedure which is described, determinations have been made of the reactions of oxygen and nitrogen, at initial gas pressures of 0.2-0.5 atmospheres, with commercial-purity (75A) titanium at 700°-1050°C. For both oxygen and nitrogen the reactions obey the parabolic rate law, but the reaction rate of oxygen is ~ 50 times as large as that

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of nitrogen. The activation energies are: with oxygen, 47,400 cal./mole (above 700°C.); with nitrogen, 45,400 cal./mole (above ~800°C.). Surfaces reacted with oxygen show the presence of TiO_2 (rutile), TiO, and titanium, the oxide thickness being extremely small at 650°C., but appreciable at 800°C.; nitrogen-reacted specimens exhibit TiN and titanium only. 5 references.—MA. 7610

6.3.15, 3.4.8

The Rate of Dissolution and the Passivation of Titainum. M. E. STRAUMANIS AND C. B. GILL. *J. Electrochem. Soc.*, **101**, No. 1, 10-15 (1954) Jan.

Experiments with hydrochloric acid and sulfuric acid showed that titanium is rapidly attacked by acids containing soluble fluorides. The rate of dissolution of titanium increases only slightly with concentration of hydrochloric acid or sulfuric acid, but rapidly with increased concentration of ammonium fluoride. Above an ammonium fluoride concentration of ~3M, titanium is passivated and its potential drops to —0.94 V. (hydrogen scale). It is postulated that the hydrogen fluoride liberated in acid solutions containing fluorides partially dissolves the protective film on titanium, and H^+ is then discharged at local cathodes which are exposed to the acid. Passivation at high ammonium fluoride concentration is said to be due to the formation of a protective salt film and to increase of the hydrogen overvoltage by the ammonium fluoride present. 13 references.—MA. 7658

6.3.15, 3.7.2

Tin Increases Strength of Titanium-Aluminum Alloys Without Loss in Fabricability. W. L. FINLAY, R. I. JAFFEE, R. W. PARCEL, AND R. C. DURSTEIN. *J. Metals* (Trans. AIME), 6, No. 1, 25-29 (1954).

The effects of adding up to 5% tin to high- and commercial-purity titanium-aluminum alloys are described. The commercial alloy—of the substituitonal type—with a nominal content of aluminum 5 and tin 2.5%, and having a total interstitial content of 0.1-0.2% (carbon+nitrogen+oxygen), has the following properties: d = 4.44 g./c.c.; U.T.S. = 120,000 lb./in.^{2}; 0.2% offset yield strength = 110,000 lb./in.^{2}; reduction in area = 40% elongation (on 1 in.) = 20%; elastic modulus = 16 x 10^6 lb./in.^{2}; endurance limit under complete reversal of stress = 70,000 lb./in.^{2}. It is single-phase, all α, up to 1900°F. (1035C.), and becomes all β above the β transus temperature, ~2000°F. (1095°C.); forging should be carried out at 1850°-2150°F. (1010°-1175°C.), other fabrication at approximately 1560°F. (850°C.), and annealing at 1600F. (870C.); it welds excellently, and is more resistant to oxidation than β-titanium; its marine and chemical corrosion-resistance is similar to that of unalloyed titanium. The interstitial content of carbon, nitrogen, and oxygen accounts for the commercial alloy being stronger than the + high-purity material. All compositions are in wt.-%. 5 references.—MA. 7633

6.3.15, 3.7.3

Fusion Welding of Commercially Pure Titanium. F. H. STEVENSON. Aerojet-General Corp. Paper before AWS, 34th Nat. Fall Mtg., Cleveland, Oct. 19-23, 1953. *Welding J.* (N. Y.), Suppl., **33**, No. 3, 147s-153s (1954) March.

Techniques for producing acceptable welds in commercially pure titanium and superiority of some procedures are discussed. Results show that fusion welds can be made using standard, inert-gas-shielded arc-welding equipment. Helium is preferred as a shielding gas when welds are made mechanically and argon when welds are made manually. No benefit was realized from stress relief of the welded joint. Tables and illustrations.—INCO. 7618

6.3.20, 1.6

Zirconium. G. L. MILLER. Book, 1954, 382 pp. Butterworths Scientific Publications, London. Academic Press, Inc.

Field covered includes occurrence and world resources, uses, extraction from the ore, separation from hafnium, production of the metal, atomic structure, physical properties, mechanical properties of the metal and of zirconium-base alloys, reactions with common gases, chemical properties and corrosion resistance, alloys, melting practices, fabrication, powder metallurgy, special zirconium compounds, metallography. We have now reached a stage in zirconium metallurgy where a large amount of information, accumulated in the last decade, requires proper digestion before future tasks (such, e.g., as the development of new production methods) can be undertaken. Dr. Miller's book, which is packed with practical detail, therefore appears at the psychological moment. Incidentally, in this field, it is the only systematic account. (The American Society for Metals symposium, published last year, was a collection of separate papers: valuable as it is, it is not a book of general reference. See card no. 6296, classified 6.3.20, 1.6). The present volume is well documented, and a very respectable number of references are dated 1953.—BNF. 7607

6.3.15, 1.6, 3.5.9, 3.7.2

Titanium Alloys for Elevated Temperature Application. WILLIAM F. CAREW, FRANK A. CROSSLEY, HAROLD D. KESSLER, AND MAX HANSEN. Armour Research Foundation (WADC-TR-52-245), May, 1953, 135 pp.

The theroretical aspects of the development of titanium alloys for use at elevated temperatures are presented. The results of a preliminary tensile test survey of binary alloys are given. These results indicate that aluminum is one of the most promising strengtheners of titanium at elevated temperatures. Therefore, titanium-aluminum alloys were used as a base for ternary alloys which were surveyed by means of the hot-hardness test. From the results of this survey 12 ternary alloys and two binary titanium-aluminum alloys were selected for further differentiation by creep rupture testing. Some creep rupture results at 425 and 550° C. are reported and give considerable promise for the development of alloys having equivalent if not better properties than type 403 stainless steel (13 percent chromium, balance iron). Concurrently with the hot-hardness survey programs, stabilization studies were made as an aid in developing heat treatments for these alloys. Oxidation studies were made on some of the alloys and are reported.—NSA. 7493

6.3.15, 3.5.9

Properties and Structure of Titanium After 30-Min. Heating at 1200 to 2000° F. E. WALDEN AND L. A. DIXON. Lockheed Aircraft Corp. *Metal Progress*, **64**, No. 2, 88-89 (1953) Aug.

Investigation indicates that annealed titanium may be used for applications involving very short exposure (30 min. max.) at temperatures up to 1500° F. in air. Above this the material becomes excessively brittle as the result of its reaction with gases in the air. Prolonged exposure of titanium to temperatures above 1000° F. produces similar embrittlement. Room-temperature tensile strength of the titanium sheet increases to a slight maximum after heating to 1500° F. and rapidly decreases after heating above 1700° F. Grain growth is quite pronounced above 1700° F. Tables.—INCO. 7229

6.3.15, 3.5.9

Titanium Alloys Give Promise of High Temperature Applications. F. A. CROSSLEY AND H. D. KESSLER. *J. Metals* (Trans. AIME), Section 1, **6**, No. 2, 119-121 (1954) Feb.

Short-time tensile, creep and stress-rupture properties; structural stability. Authors (Armour Research Foundation) conclude that "there is little doubt that titanium-base alloys will be applied with success up to 1000° F. (538° C.) for exposures of approximately 1000 hr." Alloys titanium—6 percent aluminum—0.5 percent silicon and titanium—8 percent aluminum—4 percent molybdenum are said to be superior to Type 410 stainless steel. Aluminum additions to α — or $\alpha\beta$ — titanium alloys seem to give best high-temperature properties. Alloys for service above 426° C. should contain 6-8 percent aluminum, but to obtain sufficient room temperature ductility aluminum content should be kept as low as possible. Only slight discussion on oxidation at elevated temperatures.—BNF. 7523

6.3.15, 3.7.2

Effect of Iron on Hardness, Bend Properties and Welding of Titanium Sheet. W. J. BARTH AND A. L. FEILD, JR. *Metal Progress*, **64**, No. 5, 74-77 (1953) Nov.

0.5 percent iron has little effect on room-temperature mechanical properties of commercial-purity alpha-material (titanium containing oxygen, nitrogen, carbon and up to 0.25 percent iron) in the range of 55,000-70,000 psi. yield strength. One percent iron had pronounced strengthening effect. Published work by other investigators indicates that addition of 0.25 percent iron has negligible effect on creep characteristics.—BNF. 7410

6.3.15, 3.7.2

The New Metal Titanium. MAURICE COOK. Imperial Chemical Industries, Ltd., Birmingham, England. *J. Inst. Metals* (London), **82**, 93-106 (1953) Nov.

The history of titanium and the present developing production position are reviewed with reference to the technological problems peculiar to the metal in regard to its extraction and processing. The abundance of titanium ores and the properties of the metal and those of its alloys so far developed, indicate its possibilities as a basic or large-tonnage metal, but the essential requirement for its eventually attaining this position is the devising of cheaper production methods. After a brief survey of the extent and availability of titanium ores, methods for its production are described, and details are given of its purification. The technology of arc melting titanium is described. The effect of impurities, par-

ticularly oxygen, nitrogen, carbon, and hydrogen, on the properties of the metal and its fabrication, its physical, mechanical, and corrosion-resistance characteristics are broadly considered. After noting the early work on alloy development, the structural features and properties of alloys now available are briefly described in the light of the constitutional effect of the elements used, and an indication is given of some of the chief differences between single-phase and duplex alloys.—NSA. 7499

6.3.15, 3.7.3, 3.4.6

Effect of Atmospheric Contaminants on Arc Welds in Titanium. J. C. Barrett and I. R. Lane, Jr. Federal Bur. Mines. Paper before AWS, Nat. Spring Mtg., Houston, June 16-19, 1953. *Welding J., Suppl.*, **33**, No. 3, 121s-128s (1954) March.

Effect of oxygen, nitrogen, hydrogen and water vapor on the physical properties of inert-gas-shielded tungsten arc welds in titanium. Properties of the welds are evaluated by tension, bend and hardness tests, and, in the case of the ½-in. stock, by impact tests at various temperatures. Macrostructures and tables.—INCO. 7439

6.3.15, 5.9.2

How to Descale Titanium. A. E. Durkin. *Materials & Methods*, **38**, No. 4, 107-109 (1953) Oct.

Author shows that light scale can be satisfactorily removed, without embrittlement of titanium and with low metal loss, by mineral acid treatment; heavy scale is best removed by the Kolene No. 4 electrolyte process (caustic type bath marketed by Kolene Corp.) and the Virgo salt process (essentially molten sodium hydroxide bath containing 15 percent oxidizing agents.)—BNF. 7412

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2

Aluminum as a Structural Material. M. Bridgewater. *Engineering*, **175**, 762-765, 793-795 (1953) June 12, June 19.

Describes properties of magnesium-silicon-aluminum alloy H^{10} regarding specification, stress-strain curve, Young's Modulus, corrosion, density, elongation, and fatigue. Discusses design problems including deflections, instability, buckling, torsional failure, and lateral instability. Presents recent examples of aluminum structures. Graphs, photographs. 9 references.—BTR. 7395

6.4.2

The Low-Stress Torsional Creep Properties of Pure Aluminium. W. Betteridge. *J. Inst. Metals*, **82**, No. 4, 149-161 (1953) Dec.

Results of investigation of creep properties of 99.99% aluminum are interpreted as indicating that the mechanism by which the creep strain is produced is the movement of the dislocations existing in the material before test and it is not associated with viscous movements at the grain boundaries.—BNF. 7386

6.4.2

Designing Aluminium Components for Finishing. A. W. Brace. *Product Finishing*, **6**, 49-54 (1953) May.

Factors that should be considered when an aluminum component is being designed and finished. Various finishes available for aluminum and its alloys. Photographs.—MR. 7404

6.4.2, 2.2.2

Report of A.S.T.M. Committee B-6 on Corrosion Tests on Die-Cast Metals and Alloys. Am. Soc. Testing Materials, Preprint No. 12, 8 pp., 1953.

The latest results are given of exposure tests at two sites on aluminum alloys containing 1) 8% magnesium and 2) 9.5% silicon and 0.5% magnesium. The mechnanical properties of the specimens after five years' exposure are listed. An Appendix to the report gives the results of tests to determine the effect on the mechanical properties of variation in zinc content in a die-casting alloy containing 8% silicon and 4% copper (SC84A). Tests were made on a series of alloys containing 0.2-2.0% zinc, the other constituents being silicon 8.2, copper 3.5, iron 0.45, manganese 0.4 magnesium 0.02, nickel 0.20, and tin 0.01%. Zinc was found to have no detrimental effects within the range tested, and it was concluded that the maximum zinc content permitted in the specification could be safely increased from 0.6 to 1.0%.—MA. 7501

6.4.2, 2.4.2, 3.5.8

Fatigue Strength of 14S-T4 Aluminum Alloy Subjected to Biaxial Stresses. R. W. Bundy (E. I. du Pont de Nemours) and J. Marin (Penn. State Univ.) Paper before ASTM, 57th Ann. Mtg., June 13-18, 1954. Am. Soc. Testing Materials, Preprint No. 73, 1954, 12 pp.

Investigation to determine the influence of biaxial tension-tension and biaxial tension-compression stresses on the fatigue strength of a 14S-T4 aluminum alloy. The biaxial fatigue stresses were produced in a specially designed testing machine by subjecting a circular thin-walled tubular specimen simultaneously to pulsating internal pressure and fluctuating axial tension or compression. The influence of various ratios of the biaxial stresses on the fatigue strength was investigated. Results show that the fatigue strength is greatly affected by the anisotropy of the material. Attempts are made in this paper to interpret the test results by using a modified energy theory of failure which provides for anistropy of the material. 13 references. —INCO. 7489

6.4.2, 3.2.2

Gas Content and Electrolytic Etching Behaviour of Aluminium. F. J. Burger and V. F. G. Tull. Nature (England), **172**, No. 4381, 729-730 (1953) Oct. 17.

If aluminum is etched in an electrolytic cell, with a 0.2 N sodium chloride solution as the electrolyte, at a temperature of 90°C., and using current densities of 0.1—0.2 amp./sq. cm., different patterns of attack may be observed with different samples of aluminum. Pure aluminum rolled foils (99.8%) were given an identical etching treatment. They showed two types of attack: widespread over the whole surface or strongly localized. In heating the foils to 600°C. blistering occurred with some samples and a strong correlation was found between the blistering and the etching behavior. As it is known that blistering in heat-treated aluminum is due to hydrogen it seems that the etching behavior is also correlated with the hydrogen of the aluminum.—ALL. 7396

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6.4.2, 3.2.2

Radioactive Tracers in the Study of Pitting Corrosion on Alumium. P. M. Aziz. *J. Electrochem. Soc.*, **101**, No. 3, 120-127 (1954) Mar.

Radioactive cobalt and lead ions in solution have been used to study the distribution of local cathodes on aluminum alloy specimens which were actively pitting, and to study the processes of film breakdown and repair on aluminum alloy specimens after introducing them into a corrosive environment. In the study of pitting, radioactive ions were introduced into the solution after pitting of the sample had proceeded for a predetermined length of time. The tracer was then permitted to plate out onto local cathodes, and, after washing and drying autoradiographs of the surface were prepared. Results indicate that after a pit is a few hours old it is surrounded by a ring of cathodic surface and outside this is an annular ring of passive surface which prevents lateral expansion of the corrosive attack, the remainder of the surface being cathodic. In the study of the mechanism of film breakdown and repair, samples with different surface treatments were placed in the solution and radioactive ions were introduced after various predetermined times, exchange permitted to take place, samples washed and dried, and autoradiographs prepared of the surface. Results indicate that, on contact with the solution, the surface oxide film breaks down and is then replaced by reaction with the solution. 7447

6.4.2, 3.5.8, 3.7.4

Mechanism of Creep Deformation in High-Purity Aluminum at High Temperatures. H. C. Chang and N. J. Grant. Massachusetts Institute of Technology. *J. Inst. Metals*, **82**, Pt. 6, 229-235 (1954) Feb.

Creep of very coarse-grained high-purity aluminum at 400°, 700° and 1100°F. over a stress range from 50 to 1200 lb./sq. in. and simultaneous observations and measurements of localized strains on polished specimen surfaces by means of a high-temperature microscope showed that slip is the fundamental mechanism of deformation for both single-crystal and polycrystalline materials even in high-temperature creep; component creep curves, measured between two closely spaced markings, obtained across grain-boundary-affected slip bands show a periodic behavior; and subgrains are formed under conditions where slip development is restricted. Two types of subgrains, one caused by deformation bands and the other by kinking bands, are observed and discussed. Graphs and 12 references.—INCO. 7279

6.4.2, 3.5.9

Influence of Temperature on Rate of Corrosion of Aluminum and Certain Aluminum Alloys. (In Russian). G. V. Akimov and V. V. Romanov. *Doklady Akad. Nauk SSSR*, **91**, No. 2, 281-283 (1953) July 11.

Tests were made on aluminum-copper alloys, aluminum-magnesium alloys, and commercially pure aluminum. Graphs. 3 references.—BTR. 7191

6.4.2, 3.2.2., 4.6.6

Laboratory Studies on the Pitting of Aluminum in Aggressive Waters. T. E. Wright and Hugh P. Godard. *Corrosion*, **10**, No. 6, 195-198 (1954) June.

Tests indicate the pitting tendency of Kingston tap-water is a result of its intrinsic composition and not a consequence of contamination from the city water system. It is shown that movement of water reduces both pitting probability and rate and that beyond a certain velocity, no pitting occurs. Tap water was compared with Lake Ontario Water.

Several variations of specimen preparations were investigated including boiling in water. Specimens were cut from 2S, and 3S, and 57S sheet aluminum alloy. Tables. 7604

6.4.2, 3.5.8

Dynamic Creep and Rupture Properties of an Aluminum Alloy Under Axial Static and Fatigue Stress. F. W. De-Money and B. J. Lazan. Univ. Minn. Paper before ASTM 57th Ann. Mtg., June 13-18, 1954. Am. Soc. Testing Materials, Preprint No. 71, 1954, 14 pp.

Fatigue, stress-rupture, and creep data obtained under various combinations of mean and alternating axial stress are presented and discussed for rolled aluminum alloy 24S-T4 at 300 and 500°F. The data are presented as S-N curves and stress-range diagrams to show the effect of temperature, alternating-to-mean load ratio, and stress magnitude on the fatigue, stress-rupture, and creep properties. The effect of temperature and alternating-to-mean load ratio on the characteristics of the creep curve is discussed on the basis of static and dynamic types. The role of both creep and fatigue as factors in rupture is discussed with particular reference to temperature and alternating-to-mean load ratio. 8 references.—INCO. 7667

6.4.4, 5.9.4, 3.2.3

The Anodic Oxidation of Magnesium Metal: Evidence for the Existence of Unipositive Magnesium. Roy L. Petty, Arthur W. Davidson and Jacob Kleinberg. *J. Am. Chem. Soc.*, **76**, No. 2, 363-366 (1954) January 20.

When electrolysis of an aqueous solution of any one of several salts is carried out between magnesium electrodes in a divided cell, the metal dissolves anodically with an initial mean valence number appreciably lower than two. Such dissolution is accompanied by anodic evolution of hydrogen, in amount corresponding to oxidation from the measured mean valence state to the familiar dipositive magnesium ion. In the presence of any one of a variety of strong oxidizing agents, such as permanganate or chlorate ion, another reduction product in addition to gaseous hydrogen is observed in the electrolyte, and the quantity of anodic hydrogen is found to be decreased. No such reduction product, however, is observed at the magnesium cathode. When electrolyses are carried out in a cell in which electrolyte continually flows past the anode from a reservoir at a higher level, and the oxidizing agent is not permitted to come in contact with the anode, a reduction product is again observed in the vicinity of this electrode. All these facts may be explained in terms of a primary electrode reaction consisting in part of oxidation of magnesium to the unipositive state.—ALL. 7643

6.6 Non-Metallic Materials

6.6.4

Asbestos Resin Compositions in the Chemical Industry. P. L. McWhorter. Haveg Corp. *Corrosion* (News Section), **10**, No. 4, 1 (1954) April.

Two major grades of Haveg are used in chemical industry equipment. Haveg 41, inert asbestos base with a selected phenol-formaldehyde type of resin, is resistant to acids of most types, as well as to practically all salts and many solvents. Haveg 60, inert asbestos base with a furane type of resin, is quite resistant to most acids, is fully resistant to alkalis, to practically all salts and to a very wide range of solvents. Neither type is suitable for use with strong oxidizing acids, such as nitric or chromic. Both are recommended for service at temperatures as high as 265°F. (130°C.). —INCO. 7576

6.6.5, 4.5.3, 2.2.6, 7.2

Effect of Exposure to Soils on the Properties of Asbestos-Cement Pipe. Melvin Romanoff and Irving A. Denison. *Corrosion*, **10**, No. 5, 169-179 (1954) May.

The final results of a study of two varieties of asbestos-cement pipe after exposure to a wide variety of soil conditions for a maximum of 13 years are reported. The data presented in a previous paper indicated that certain mechanical and physical properties of the material are affected by exposure to the soils. The samples of asbestos-cement pipe gained appreciably in strength during the early periods of exposure, thus indicating that the curing process continues for several years during exposure underground. The present paper summarizes the previously published data and reports the effect of the same soils on the pipe samples after completion of the curing period. The effects of exposure to the soils on the properties of asbestos-cement pipe are indicated by measurements of hydrostatic bursting pressure, crushing strength, water absorption, apparent specific gravity and condition of the surface of the specimens removed. 7645

6.6.8, 7.3

Glass-Plastic Blade Passes 100-Hr. Test. I. Stone. *Aviation Week*, **60**, No. 14, 43-46 (1954) April 5.

Inspection of fibrous glass-reinforced plastic rotor blades, developed by Thompson Products, Inc., in a military turbojet compressor after a 100-hr. run at rated engine speed showed that they were in perfect condition, exhibiting no signs of impending failure or erosion. Blade possesses many advantages, including relatively high damping capacity, low mass weight, low creep rate, high strength weight ratio and high impact strength. Disadvantages include non-isotropic strength properties and difficulty of adequate inspection. Temperature limitations do not appear to interpose any significant hurdle. Graphs give relative properties of various compressor blade materials—403 stainless, TP-1 (Thompson Products sintered iron powder), titanium alloy, glass-plastic (phenolic resin) and aluminum alloy. Illustrations.—INCO. 7639

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6.7 Duplex Materials

6.7.2

Fundamental Study and Equipment for Sintering and Testing of Cermet Bodies. VI. Fabrication, Testing, and Properties of 72% Chromium—28% Alumina Cermets. THOMAS S. SHEVLIN. Ohio State Univ. *J. Am. Ceram. Soc.*, **37**, 140-145 (1954) March.

Physical properties, including firing shrinkage, density, modulus of rupture from 75 to 2400°F., stress-rupture life in cross bending and in tension at 1800 and 2000°F., modulus of elasticity, tensile strength from 75 to 2000°F., comparative impact resistance, oxidation resistance, thermal expansion, and thermal-shock resistance, for the composition 28% alumina-72% chromium combine to indicate the potential value of this material in high-stress applications at elevated temperatures where severe thermal shock may be encountered. While the thermal-shock resistance is much better than that possessed by the low-chromium high-alumina bodies, the mechanical properties at elevated temperatures do not appear to suffer as a result of the highly continuous metal phase in the more reecntly developed body.—NSA. 7569

6.7.2, 3.5.9, 3.2.3

Oxidation Resistance of Ternary Mixtures of the Carbides of Titanium, Silicon, and Boron. O. E. ACCOUNTIUS, H. H. SISLER, T. S. SHEVLIN AND G. A. BOLE. Ohio State Univ. Paper before Am. Ceramic Soc., 55th Ann. Mtg., N. Y., April 29, 1953. *J. Am. Ceram. Soc.*, **37**, No. 4, 173-177 (1954) April.

Dense compacts of mixtures of TiC, SiC, and B_4C were prepared by sintering in an argon atmosphere and by hot pressing. TiC and B_4C reacted during heating to form TiB_2. The oxidation resistances of these ternary compacts were determined by the weight gained at 2000°F. in air. Compacts containing 10% B_4C, 70—50% TiC, and the remainder SiC had superior oxidation resistances. The oxide coating on these compositions consisted of rutile, silica, and an amorphous third phase. A compact composed of 73.5% TiC, 17% Si, and 9.5% B was hot-pressed. It had zero porosity and better oxidation resistance than any other composition tested.—INCO. 7449

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1

Evaluation of Bearing Materials. P. G. FORRESTER AND W. E. DUCKWORTH. *Research Correspondence* (Supplement to Research), **6**, No. 11, 57S-60S (1953) November.

Comparative tests on tin-base white metal, copper-45% lead and copper-30% lead bearings by fitting them in the engine of a private car. Results indicate that difference between white metals and copper-lead is due to a surface characteristic. All bearings were pitted by lubricant-carried abrasive particles of steel, aluminum and copper-lead, but the white metals showed much less tendency to retain these. Also tests on electrodeposits of tin, lead-tin, and lead-indium on copper-lead.—BNF. 7472

7.1

Bearing Failures—Diagnosis and Prevention. H. W. LUETKEMEYER. Clevite-Brush Dev. Co. Paper before API, Lubrication Comm. Mtg., Detroit, Feb., 1953. *Petroleum Refiner*, **32**, No. 7, 135-137 (1953) July.

Bearing failures are identified as one of or a combination of fatigue, seizure and wiping, corrosion, erosion, and wear, abrasion and scoring. Analysis of why bearings fail and the proven methods for curing these ills are covered.—INCO. 7077

7.1

Maintenance of Marine Turbines. R. O. BUTCHER. Gen. Electric Co. *Marine Engineering*, **58**, No. 7, 43-48 (1953) July.

Discussion on the proper maintenance of marine turbines which includes five rules of maintenance, and factors involved in providing proper operating care, and proper inspection and overhaul procedures. Water acting as an abrasive causes erosion and water-cutting, and water vapor left in contact with ferrous-metal parts causes corrosion. Deposits will form on any turbine parts where the steam in contact with this part carries salt or boiler compound. Suggested inspection program and common causes of turbine operating difficulties are tabulated. Illustrations.—INCO. 6256

7.3 Pumps, Compressors, Propellers and Impellers

7.3

Causes of Corrosion in Deep Well Water Pumps in Israel. A Technical Note. *Corrosion*, **10**, No. 4, 122-123 (1954) April.

Among the causes of corrosion of deep well water pumps in Israeal are galvanic currents caused by temperature differential cells between the upper and lower portions of well liners and pump components; galvanic corrosion from incompatible metals; and discharges of current from interconnected piping systems. These currents were held responsible for damage to screens and to pump components, especially driving shafts, which in some cases was so serious as to cause abandonment. 7522

7.4 Heat Exchangers

7.4.1, 4.6.4, 8.8.1

Improved Equipment Helps Maintain High Heat Transfer. *Steel News*, **7**, No. 4. 18 (1954) April; *Industry & Power*, **66**, No. 4, 58 (1954) April; *Iron Age*, **173**, No. 14, 174-174A, 176, 178 (1954) April 8.

New type coated cooling section and use of Naval bronze rather than steel bolts in Am. Cyanamid Co.'s plant, Linden, N. J., solved a corrosion problem where cast iron cooling equipment used in the production of sulfuric acid is continually subjected to raw sea water. Corrosive action was aggravated by sulfuric acid temperatures as high as 225°F. for the entering 98% acid which promoted evaporative cooling which left salt deposits on the cooling coils. Corrosion on the water side was severe enough to build heavy scale which reduced the rate of heat exchange and promoted the growth of algae. Sections coated with Kolmetal (a mixture of 85% aluminum powder by volume in a plastic vehicle) show practically no traces of corrosion or algae after more than 1 year's service.—INCO. 7679

7.4.2, 8.4.2, 2.2.3

Shell's Experience with Corrosion in Gas Treaters. R. G. WRIGHT. Shell Oil Co. Paper before N.G.A.A. Ann. Mtg., Dallas, April 21-23, 1954. *Oil Gas J.*, **53**, No. 7, 161, 168 (1954) June 21.

Practically all corrosion in the heat-transfer equipment at Shell-Colombian Carbon Girbotol gas treater has occurred to the reboiler tubes and solution cooler tubes. A complete Monel No. 304 tube bundle with Monel clad tube sheets was badly corroded after one year. At present, a tube bundle is being prepared which will test 10 different ferrous alloys: Monel, Inconel, stainless steels 304, 310 and 316, Carpenter 20, 12% chromium, Croloy 5, nickel-plated seamless carbon steel and Inco alloy 803.—INCO. 7625

7.5 Containers

7.5.5, 5.2.1

Cathodic Protection of Storage Tanks. *Diesel Power*, **32**, No. 2, 30-32 (1954) February.

Description of the way Chicago and North Western Railway cuts maintenance costs by cathodic protection of fuel and water storage tanks from the time of installation. Nature and cause of corrosion as related to underground and submerged, and the cathodic protection system are briefly discussed. Illustrations.—INCO. 7656

7.6 Unit Process Equipment

7.6.4, 4.6.2, 5.8.2, 5.7.7

Treating High Pressure Boilers. J. A. ULRICH, JR. E. F. Drew & Co., Inc. *Mariner*, **1**, No. 3, 28-29, 42 (1954) March.

High pressure marine boilers have brought about the need for better protection of boiler watersides. Definite improvements were noted when alkali and phosphate were used with a volatile alkali to raise the pH of the condensate and feed water plus a nitrite type of material, organic ACR, to prevent adherence of iron oxide as "iron oxide scale." This type of treatment in marine boilers operating at 450 psi to 850 psi proved satisfactory. All deposits on the watersides of tubes were eliminated and no manual or chemical cleaning of boiler watersides was found necessary.—INCO. 7678

7.7 Electrical-Telephone and Radio

7.7

Aluminum Connector Requirements Set Up. I. MATTHYSSE AND H. P. DUPRE. *Elec. World*, **141**, No. 8, 105-107, 200 (1954) Feb. 22.

Proper design and installation of aluminum connectors which join aluminum and copper conductors are vital factors for long life and troublefree service particularly in corrosive atmospheres. Such connectors should meet the following requirements: 1. The aluminum body

should be massive in comparison to the copper conductor to minimize electrolytic action. 2. The connector should be unbushed to avoid corrosion between bushing and connector. 3. The design of the connector must protect the aluminum conductor from electrolytic attack. A bare aluminum connector in direct contact with the aluminum conductor and with wide separation between the aluminum and copper conductors provides this protection. 4. The contact grooves should enclose the conductors to minimize the conductor area. This aids in retaining the compound and resisting corrosion. 5. The connectors should have proper contact areas, should exert correct pressures, and use materials having the proper physical properties to allow for differences of expansion coefficients, creep and relaxation. Service and laboratory tests have proved that a correctly designed aluminum connector needs no bushings or liners in the groove that holds copper conductor. 7575

7.7, 6.6.5, 6.4.2

Corrosion Problem Solved. E. TRELA. Apex Smelting Co. *Modern Metals,* **10,** 72, 74, 76 (1954) April.

Corrosion of aluminum base duct boxes is due to moist and caustic conditions from uncured cement in new construction, the joining of the iron conduit directly to the aluminum box forming a galvanic cell, stray electric currents in the duct forming an electrolytic cell effect, and choice of the wrong aluminum alloy. Alloy S5A (aluminum-5% silicon) is the recommended material for this application because of its corrosion resistance and good casting properties. Other recommendations include waiting for the cement to set and cure, coating the boxes with protective coatings, coating concrete recesses with coal tar base material, and using fibre or phenolic connecting rings to join iron conduit with the aluminum box to avoid intimate metal-to-metal contact.—INCO. 7684

7.8 Wires and Cables (non-electrical)

7.8, 7.7, 1.6

The Wire Industry Encyclopaedic Handbook. Book, 1954, 448 pp. The Wire Industry Ltd., London.

The format is similar to that of previous years. 15 pages are devoted to a series of 7 short articles ranging from the Bonderizing process to the care of wire ropes. The usual contents include a list of informative articles which have appeared in *The Wire Industry* during the past six years, and the wire tables. The latter are unchanged except for the omission of a molybdenum table.—ZDA. 7630

8. INDUSTRIES

8.1 Group 1

8.1.2, 6.6.5, 6.4.2

The Use of Aluminum As Form Material in the Artificial-Stone and Building Industry. D. EMTER. *Aluminum,* **30,** No. 2, 67-71 (1954) Feb.

The Laboratories of the Aluminiumwerke Nurnberg G.mb.H. have made a number of tests to investigate the behavior of commercial aluminum alloys towards different types of concrete. Three aluminum alloys: GAlSi (Silumin.) GAlMg3 (Hydronalium) and GalSi 6 Cu 3 (similar to Nural 85 K) have been tested. Aluminum-magnesium (3%) alloy showed best resistance against concretes. However, the tests proved that in setting, the cements attack the aluminum, which not only limits the life of the forms but also lowers the quality of the concrete surface. Therefore a number of protective coatings have been developed among which the following seemed most suitable. 1. Silicone resins; aluminum forms treated with silicone resins showed not the slightest reaction with the concrete even when the most aggressive Portland lacquers; forms coated with asphalt paint could be used five to six times before reaction occurred. 3. Cellulose lacquers; better than asphalt paints, cellulose lacquers showed no deterioration even when the most aggressive Portland cement was used and guaranteed full protection for the aluminum form for more than 10 operations. 4. Rubber spraying is an ideal protection for aluminum and its alloys.—ALL. 7615

8.4 Group 4

8.4.1, 8.9.4, 6.4.2

Aluminum Alloys in Hopper Cars. E. T. ENGLEHART, JR. AND G. B. HAUSER. Alcoa *Ry. Locomotives & Cars,* **128,** No. 5. 62-66, 70 (1954) May; *Ry. Age,* **136,** No. 22, 43-45 (1954) May 31.

Performance of aluminum alloys in the experimental hoppers as indicated by the results of detailed tests was substantiated by similar examinations of samples removed from coal hopper cars in service.

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Different types of coal having various sulfur contents were placed in the hoppers to determine the effect on the aluminum alloys employed in the hoppers. Another hopper composed of copper-bearing steel with sloping side sheets of high strength-low alloy steel (containing 0.04% nickel) was added to the test. After 20 years, aluminum alloy hoppers appeared in good condition and had resisted attack by the various types of coal to the same extent. Low-alloyed steel members had suffered severe thinning and large perforations. Graphs show the results of attack of aluminum and steel parts, and the resistance to corrosion of 4S alloy to different types of coal. Tables.—INCO. 7668

8.4.3

Inspection of Petroleum Refinery Equipment. EDWARD H. TANDY. *Corrosion*, 10, No. 5, 160-164 (1954) May.

The conditions created by the presence of corrosive compounds in crude oils, the formation of corrosive compounds during processing and by the use of corrosive process chemicals makes constant inspection of refinery equipment necessary. The refinery equipment inspector must be familiar with construction and operation so he can anticipate and forestall expensive replacements. Corrosion caused by hydrogen sulfide formed during distillation by the break-down of sulfur compounds usually can be predicted. However, the inspector always must be alert for localized overheating which will accelerate the corrosion rate. Naphthenic acids are most corrosive at their condensation points. Their presence in the crude oil or their formation during refining may cause severe localized corrosion wherever they are condensed or evaporated. Corrosion in gasoline storage tanks caused by moisture, oxygen and slight concentrations of other gases, proceeds at a low rate as compared to corrosion in distillation equipment. Nevertheless, it is responsible for major repairs. 7627

8.4.3, 4.4.6, 4.2.3

More From the Bottom of the Barrel. Pt. 1—Heavy Fuel Oil. Pt. 2—Asphalt. Pt. 3—Petroleum Coke. G. WEBER. *Oil Gas J.*, **52**, No. 46, 138-154 (1954) March 22.

Part 1 discusses new processing developments which will enhance the return from residuals. Most promising approach to the solution for deposit, vanadium and sulfur corrosion problems appears to be through the use of additives. Several utilities found vanadium tolerable in high temperature steam generation. British studies conducted with miniature combusion chambers subjecting alloy samples to vanadium-containing ash at 1472°F. indicated that some alloys such as 18-8 and 20% chromium—80% nickel showed best resistance to attack, with alloys of intermediate chromium-nickel ratios being about 2-4 times less resistant. Part 2 discusses petroleum derived asphalt. Part 3 discusses petroleum coke which is now a vital ingredient in manufacturing pig aluminum. Nonfuel uses, such as electric-production, appear to be expanding. Illustrataions, 20 references. —INCO. 7681

8.4.5, 7.3, 4.7

Nickel's Roll in Nuclear Power for Submarine. *Marine Eng.*, **59**, No. 5, 122, 124 (1954) May.

A pump, capable of circulating high-temperature liquid metals, forms part of a heat-transfer system built for nuclear submarine propulsion development. Pump shaft, drain tank, and floor plate are of type 347 stainless steel. The shaft-cooler bushing and gaskets are nickel. Shaft has a Stellite facing. All bolts have a hard nickel-plate or nitrided surface to prevent galling. No liquid-metal corrosion has occurred on parts in contact with liquid-metal.—INCO. 7590

8.8 Group 8

8.8.5, 5.9.1

Controlling Corrosion in Light Metals Finishing Plants. R. R. PIERCE. Penn. Salt Mfg. Co. *Modern Metals*, **10**, No. 3, 78-80 (1954) April.

Highly corrosive agents encountered in light metals finishing plants include sulfuric acid, H_2CrO_4, caustic etching compounds, alkaline cleaners, deoxidizers, desmutters, and ordinary water. A systematic approach to the problem of protecting the machinery, equipment, and building is presented. On the basis of separate chemical operations, a distinction is made between 1. most severe, 2. frequent spillage, 3. concentrated fumes, and 4. mild concentrations of fumes. As operations are often combined in one area, the best coating system should be used throughout with individual selections for individual tanks, equipment and structural steel. Various coatings for specific conditions are discussed.—INCO. 7582

8.9 Group 9

8.9.1, 6.7.3

Al-Fin in Aeronautical Engineering. *Aeroplane* (England), **86**, No. 2223, 247-248 (1954) February 26.

The Al-Fin process for metallurgically bonding cast iron, steel and similar materials to aluminum and its alloys was developed by the Fairchild Engine and Airplane Corporation and came into general use in 1941. Rights to this process in the United Kingdom were obtained by Wellworthy Ltd., of Lymington and in this article the company has indicated the increasing use which is being made of it by aeronautical engineers. To overcome the disadvantage of low modulus of elasticity of aluminum at high temperatures found in supersonic aircraft, components are being manufactured by bonding steel inserts into points of maximum thermal and mechanical loading. A development which is still being investigated is the manufacture of wire reinforced aluminum sheet for use as aircraft skin or armor plate. Cast aluminum alloy slabs are manufactured with bonded-in stainless steel wires, and the slabs are later rolled to the desired thickness to produce the reinformed sheet. Many aircraft components, particularly in jet engines, are subjected to oxidizing or corrosive conditions and it has been found that aluminized coatings produced during the bonding stages of the Al-Fin process provide resistance to such attack at temperatures up to 900°C. They are also resistant to corrosion by combustion by-products containing sulfur compounds. Experimental work has shown that Al-Fin coated mild steel components have equal resistance to corrosion as the more expensive and strategically important chromium-nickel steels and that Al-Fin coated cast iron is rendered heat-resistant and virtually free from growth due to gas absorption at elevated temperature. Numerous applications cited.—ALL. 7616

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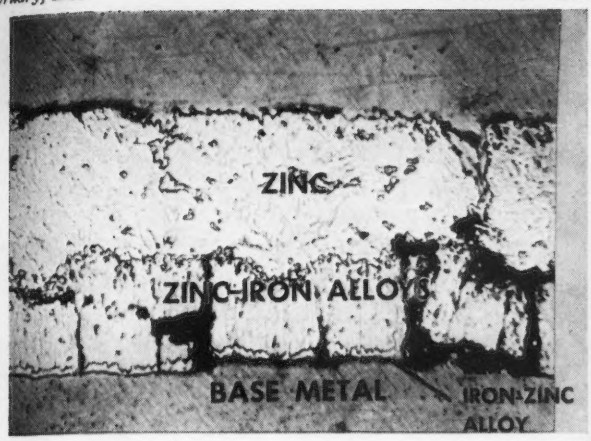
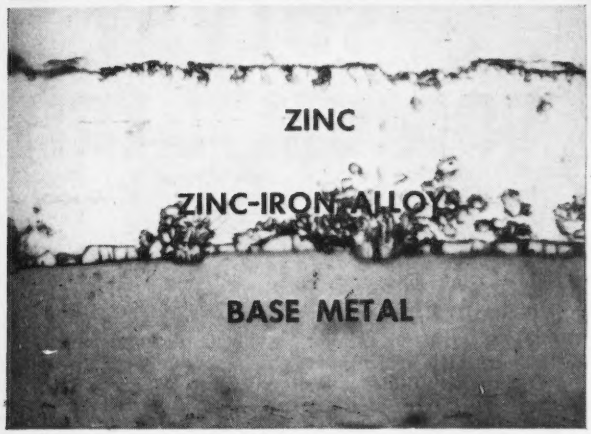


OLD Cross-section of the old type coating after the metal was stretched only 15%. Dark areas are cracks that spread from the brittle alloy layer, causing the coating to flake or peel off.

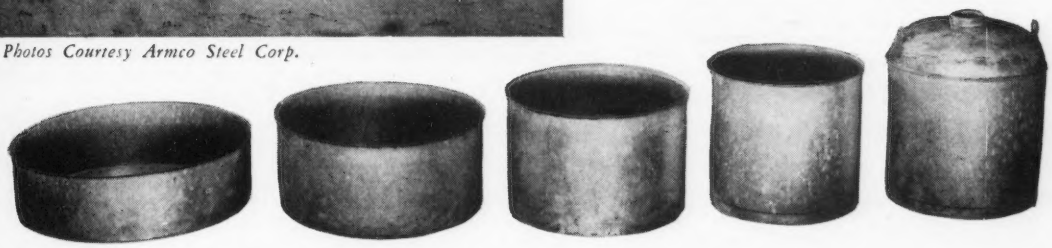


IN GALVANIZED STEEL... *a new look*

NEW Cross-section of the new type coating after 20% stretching. There is no brittle alloy layer and the zinc coating adheres tightly to the base metal.

WHAT CAN BE DONE This container, made of hot dipped galvanized steel, started as a 26⅛ in. dia. circular blank. Finished product, after four draws, is 11¼ in. in dia. and 10½ in. deep.

Photos Courtesy Armco Steel Corp.



THE CHIEF FUNCTION OF ZINC — the most generally available metal which is electro-negative to iron — is the rust-proofing of iron and steel products. Since a zinc coating provides the ferrous base with perfect electrolytic protection against rust, it is not surprising that for many years the galvanizing industry has used nearly one half of all the zinc consumed annually in the United States.

Significant changes in galvanizing methods now make it possible to produce zinc coated steel much more versatile than its predecessor material. Some of these improvements are not generally realized throughout industry.

The product of today's continuous galvanizing lines not only offers exceptional corrosion resistance but also is able to take as severe a draw as the annealed base steel without failure of the protective coating. Previously, steel with heavy zinc coatings could be cold formed only to a limited extent before flaking or peeling of the coating occurred. Continuous galvanizing, with its uniformity of coating thickness and adherence, makes it possible to produce deep drawn products with as high a degree of corrosion resistance as that of flat zinc coated stock.

The improved properties of the continuous line product have led to a much broader application of galvanized sheet and strip. Coated with zinc, they have the most flexible and versatile protective surface obtainable, and the outlook is one of ever-widening application.

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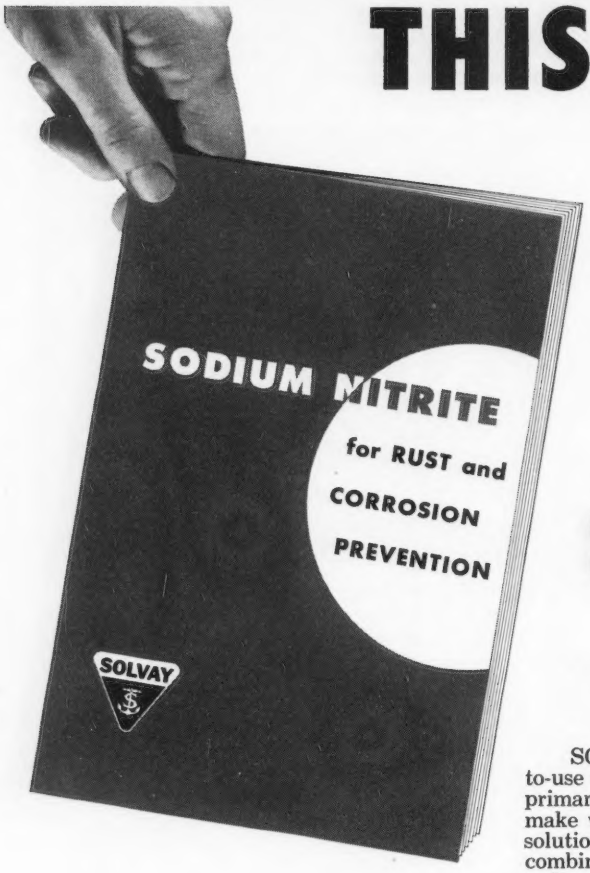

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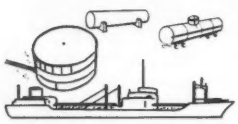
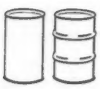
A Few Typical Applications


Hydrocarbon service and fuel oil tanks

Air conditioners, heat exchangers and other circulating water systems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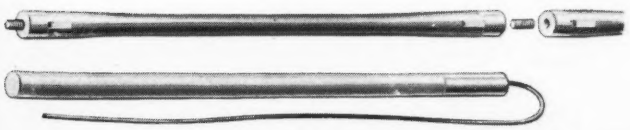

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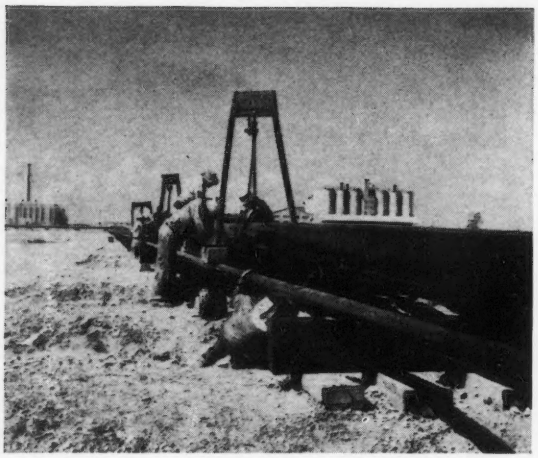
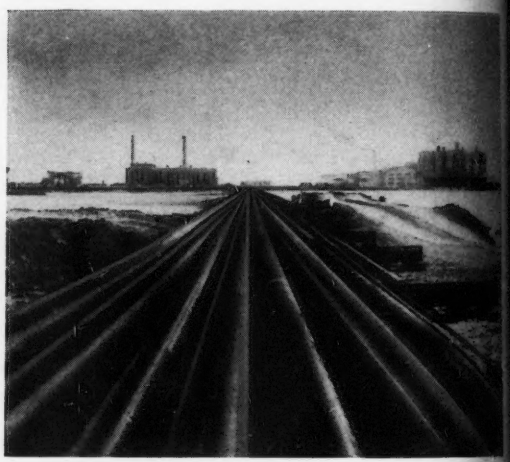
Here's how they KO'd SULPHUR, CHEMICALS SALT AIR and HEAT on this Refinery Pipe line!

1. It takes no special equipment to apply Pitt Chem. Here, applicators brush on 101 about 12 mils thick.



2. Pitt Chem applies easily, even on awkward underside. Crew learned to apply it in a few minutes.



3. Pitt Chem 101 was economical to purchase and apply. It will protect this line against corrosion for years.

MAINTENANCE engineers at this Southwestern refinery realized that no ordinary coatings could protect these pipelines from the metal-eating conditions they faced. Today, the lines are safely protected with an impervious film of *Pitt Chem*® Tar Base Coating, the material that *naturally* resists practically all major types of industrial corrosion.

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